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Some factors involved in the storage of corn in tight-walled bins

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SOME FACTORS INVOLVED IN THE

STORAGE OF CORN IN TIGHT-WALLED BINS

by

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I. INTRODUCTION

Corn production in the United States exceeds 2,000,000,000 bushels annually. Of this amount, Iowa furnishes more than 400,000,000 bushels. Much of this corn is stored on the farm to be fed or sold later. Several factors are involved in storing corn, among those most important being,

1. Protection from the weather,
2. Protection from rats,
3. A minimum fire hazard,
4. A means of conditioning corn having excessive moisture.

The last named factor is of particular importance in the storing of seed corn, and seasonal conditions frequently are such as to make conditioning necessary for ordinary market corn. Soft corn years result in heavy losses to the corn growers. More than 36% of the corn from the 1917 crop reaching six principal terminal markets went as sample grade. Much corn spoiled so badly that year it could not be sold or put to any profitable use.

The recent development of hybrid seed corn is creating a problem of early conditioning for safe winter storage.

Considerable interest is now manifest in the storage of corn in tight-walled bins instead of the usual open cribs. It is the purpose of this study to determine some of the basic factors involved in storing and conditioning corn in tight-walled bins.

II. HISTORICAL

Much of the investigational work reported on the conditioning of corn and other grains has been on the basis of the viability of the seed. Duvel (6) in 1904 reported on his investigations on the vitality and germination of seeds "that moisture plays an important part in bringing about the premature death of seeds, and that the detrimental action of moisture is more marked as the temperature increases.................... Experiments have shown that moisture is the chief factor in determining the longevity of seeds as they are commercially handled."

Bailey (2) in 1921 reported on his work dealing with the respiration of shelled corn. He made determinations of the hygroscopic moisture in shelled corn maintained in atmospheres of four different relative humidities. He pointed out the relationship between the moisture content of corn and the relative humidity of the air surrounding it.

Coleman and Fellows (3) worked with a number of grains, including corn, to determine their hygroscopic moisture at several different relative humidities. Their work was reported in 1925. Their values determined for corn were slightly higher than those obtained by Bailey. Varietal difference of the corn worked with may account for at least part of the values shown.

Duncan and Marston (5) reported in 1925 their investigations in Michigan on the curing and storing of seed corn gathered at different stages of maturity, and dried at different temperatures.

In working to determine the moisture content of corn in relation to relative humidity of the atmosphere, Alberts (1) found that "except with extremely high or extremely low relative humidities, moisture in corn is practically independent of temperature, but varies with the relative humidity. Above 90% relative humidity, the moisture content of corn was greatest at the highest temperature. Below 10% relative humidity, the moisture content was greatest at the lowest temperature." He made moisture determinations at several different temperatures. His values at 87°F. (30°C.) were between those reported by Bailey and by Coleman and Fellows.

Wright and Duffee (8) reported in 1927 on their investigational work in Wisconsin on corn drying that "warm air, if kept moving, may be used at a temperature of 130°F. without injury to germination or growth. Freshly harvested corn containing from 30 to 50% moisture may be cured in 60 to 96 hours to 12% moisture without injury to germination and subsequent growth."

In 1929 Harrison and Wright (7) reported on further investigational work in Wisconsin. They state, "to insure good seed in Wisconsin, drying corn with heated air is necessary. Ear corn when dried by forced warm air ventilation at temperatures of 96° to 104°F. (40° - 45°C) was not injured. Corn dried at 122°F. was considerably damaged, and corn dried at 140°F. was nearly all killed. Corn dried at 168°F. was completely killed. Corn dried to less than 10% moisture at non-harmful temperatures was not injured. Some was dried to 4%. Rapidity of drying is not a factor at non-harmful temperatures."

Dillman (4) in 1930 reviewed several previous investigations on the moisture content of grains, and reported his findings on the hygroscopic moisture of flax and wheat. Wheat shows very similar values to corn, while flax shows appreciably lower values, but a similar relationship between moisture in the flax and relative humidity of the air.

The foregoing investigations in addition to several others conducted during the past fifteen years all serve to emphasize the importance of moisture in the storage of corn and other grains. Only by reducing the moisture content to a favorable degree can corn be stored successfully, either for seed or for market purposes. The exact degree of dryness required varies slightly under different conditions, but in general, should meet the United States standard for No. 1 corn: namely, 14 per cent.

III. EXPERIMENTAL

A. Purpose of Study

The purpose of this study has been to correlate the results of pertinent investigations already reported, and to determine other basic requirements for storing corn in tight-walled bins. Much of the effort has been given to determining some of the air requirements of drying corn.

B. Method of Procedure

The work resolved itself into four principal phases:-

1. Observations of corn in large storage bin. The grain storage building erected during the summer of 1929 on the campus of Iowa State College, afforded splendid opportunity for observations of corn under actual storage conditions. This building comprises four circular bins, each 16 feet in diameter, and 35 feet high. The walls are of hollow tile construction, three of them being made tight of silo blocks, and the fourth one of ventilated crib tile. The two south bins have false floors constructed of 2" x 4" 's on edge and spaced 3/4 inch apart. This leaves air chambers about three feet deep beneath the false floors. Overhead bins are provided, in addition to the four circular bins mentioned above. The south east bin has served for observational purposes in this study. The building includes a dump pit, and is equipped with a stationary inside cup elevator, operated by an electric motor. Corn is

thus put in the bins by means of mechanical equipment, which probably results in a larger percentage of shelled corn than the usual hand scooping. The corn is first dumped into the pit where a horizontal conveyor is arranged to carry it to the foot of the elevator. Upon reaching the top, the corn is discharged from the elevator head into a chute leading to the desired bin. The first corn has a clear drop of forty feet, and naturally results in considerable shelling. Most of the shelled corn is found concentrated in a relatively small part of the cross-sectional area of the bin, this being directly under and in front of the corn chute.

a. To keep a check on the temperature within the bin, four electric thermo-couples were installed as the bin was filled. These couples were of copper and constantan, with their junction twisted and welded together. Thermo-couple No. 4 was set November 18, 1929, in the center of the bin, at a height of 5 feet above the floor. By November 22, the bin was filled to a height of 15 feet at which level two additional couples were set, No. 2 at the center, and No. 3 one foot from the wall, and directly under the chute from the elevator.

As the department corn did not fill the bin, couple No. 1 was left suspended in the bin, until December 17 when it was set at the center, 25 feet above the floor just prior to the filling of the remainder of the bin with corn from other sources, to an average depth slightly over 35 feet.

Temperature readings were made at intervals by means of a potentiometer. It was intended to take these readings once a week. Due to the fact the potentiometer is not designed for use when exposed to temperatures below 40°F., some irregularity occurred while devising means to maintain a suitable temperature for the potentiometer while being used in this unheated building at times of low temperatures. This problem was solved by constructing a well insulated carrying case for the potentiometer and using same in a closed car driven in the driveway of the building, and using a glow heater connected with the electric lighting circuit of the building, to maintain a suitable temperature in the car. The accuracy of the potentiometer readings was checked each time by reading a thermo-couple exposed to the air close to a high grade mercury thermometer.

With the arrival of warm weather, the temperature readings were taken at shorter intervals as may be noted in Table No. 2.

On March 14, 1930, the usual weekly readings were taken, and showed low temperatures similar to those prevailing thru the winter. However, a visit to the top of the bin gave strong indication of heating in the corn. A perceptible odor, and an appreciable warmth at the surface of the corn about where it had discharged from the chute, served to show the need for additional thermo-couples in the bin. Accordingly, a piece of pipe 4 feet long was given a sharp point and driven down into the corn at what seemed to be the hottest spot and couple No. 5

pushed into same. This gave a reading of 138°F. at a distance of 4 feet from the top, and the corn near the surface was moved to allow it to cool. An abnormal amount of shelled corn, silks and other debris were observed in the area manifesting a high temperature. As couple No. 5 still was above 100°F. on March 15, it was deemed advisable to secure additional readings to determine the extent of the corn showing a high temperature. Three additional pipes were driven on that date and couples placed in them. No. 6 was placed in the center 8 feet deep, (No. 6 was about 2 feet directly above No. 1) No. 7 near No. 5 but 12 feet deep, and No. 8 also near No. 5, but 16 feet deep. On March 19, No. 9 was driven near No. 5, to a depth of 8 feet, the same as No. 6.

b. Beginning January 10, and continuing until May 22, moisture determinations were made each week from corn near the top of this bin. The determinations were made with a Brown-Duvel moisture tester, in accordance with the standard practice. Two samples were run in each case. The kernels were tested in the regulation glass flasks, while the ground cob was tested in double-wall copper flasks.

c. To secure a measurement of the natural air flow thru the corn, the aperture below the false floor was reduced to .1 of a square foot, and equipped with a small wooden duct to make possible the use of a vane-type anemometer. The reduced aperture being 1/2000 the cross-sectional area of the bin multiplied the velocity 2000 times, and thus furnished some data on this point, although frequently the movement was too little to record with this multiplication.

d. The temperature readings on April 13 indicated a marked rise in temperature for much of the bin, so preparations were made for blowing unheated air thru it.

Tentative plans had been made to use one of the blowers used by the department of Buildings and Grounds. This blower, however, was out of order, and could not be immediately repaired. An old silo filler was pressed into use, and was located just outside the building and pipe connections made with the space beneath the false floor of the bin. Due to the design of the building, it was necessary to use four 90^{o} elbows in the connections, which doubtless greatly reduced the efficiency of the system.

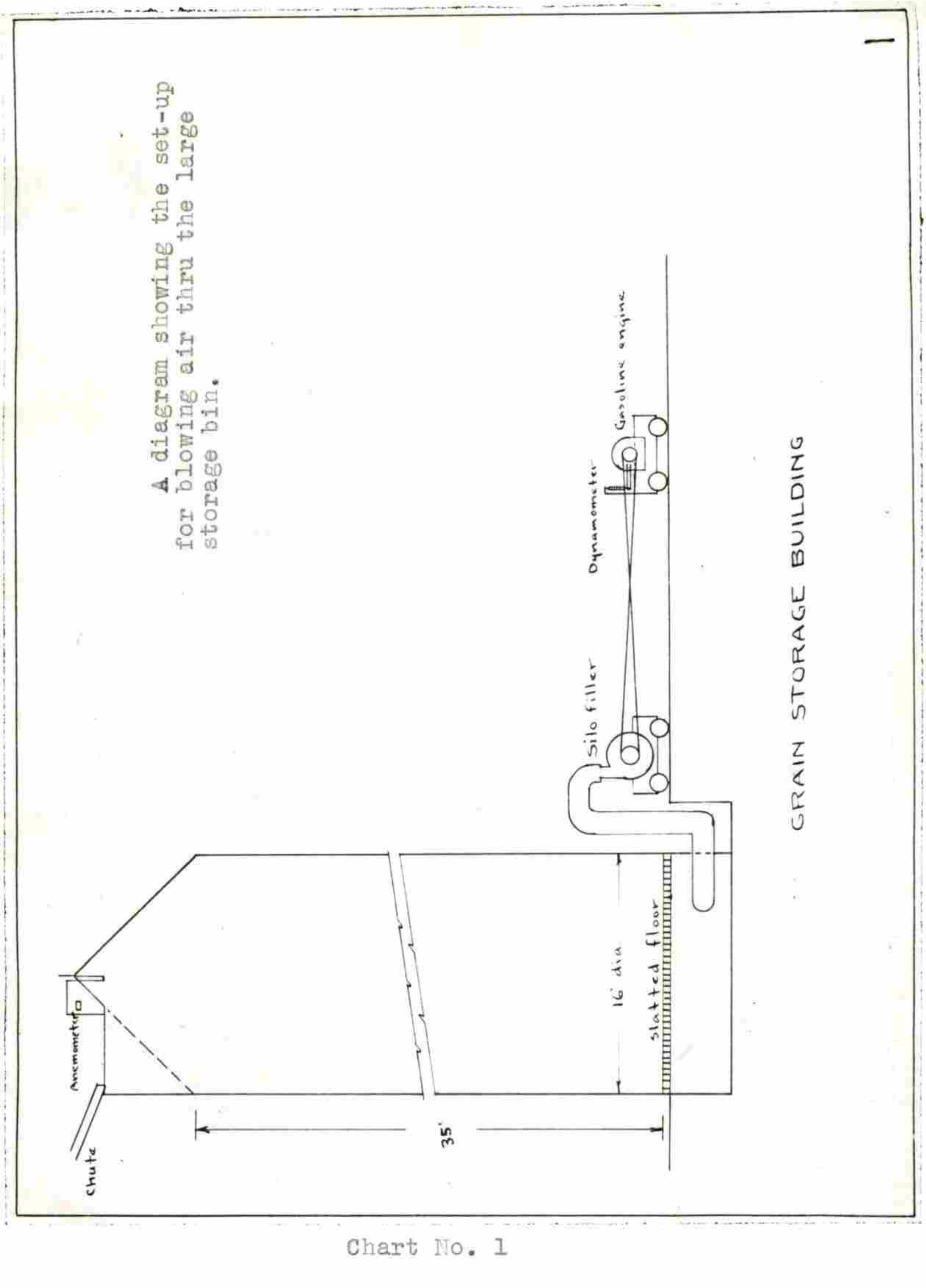
The set-up was completed on April 19 and the blower run one hour that day. Blowing was resumed April 21, a tractor being used for power. This was found needlessly large, and was replaced with an old automobile engine mounted in such a manner as to give dynamometer readings with varying speeds.

To determine the amount of air delivered at different speeds of the blower, the top of the bin was covered, except for a square duct of 5 square feet cross-sectional area. This duct was divided with wires into 9 equal areas for anemometer readings. The mean of the nine readings was used as the average velocity.

Unfortunately, the construction of the building is such it was found impractical to get satisfactory static pressure readings at the time the power and velocity readings were made. After securing the desired data on power and velocities, with varying speeds, the gasoline engine was replaced by a 5 horsepower electric motor, and the remainder of the blowing was done with it.

(1). The power determinations were made by using a revolution counter on the engine shaft, and taking two readings on the spring balance measuring the torque of the suspended engine, first running idle, and second with its load, the difference in the two readings showing the pounds pull at the end of the lever arm of known length.

(2). The amount of moisture removed from the corn was calculated by determining the relative humidity of the air entering the blower, and again when discharged at the top of the bin. A wet and dry bulb sling psychrometer was used, the velocity of the air making it unnecessary to swing it. By referring to psychrometric tables, the amount of moisture in each cubic foot of ingoing and outgoing air was found, and the difference multiplied by the number of cubic feet of air gives the amount of moisture removed. A vane type anemometer was used to determine the velocity of the outgoing air, from which the volume is readily calculated.



A diagram showing the set-up for blowing air thru the large storage bin.

Chart No. 1

Figure No. 1
The new grain storage building at Iowa State College affords splendid opportunity for investigational work.

Figure No. 2
An old silo filler was used for blowing air thru the corn. This picture shows the blower as operated by a 5 H. P. portable electric motor.

2. Work with small experimental bin. To determine some of the power and pressure factors involved in blowing air thru ear corn, and also secure data if possible on the rate of drying, a small experimental bin was constructed.

The bin has a diameter of 30 1/4 inches and a cross-sectional area of 5 square feet. It is about 8 feet high and has a false slatted floor, below which connection is made with a fan for blowing air thru the bin. The bin has a cover with outlet of .25 square foot cross-sectional area.

To quickly determine any change in moisture content, the bin was placed on platform scales having a capacity of 1,000 pounds.

The blower used was a nine blade fan 4 1/2" x 15" used for elevating ground feed from a Prater hammer mill. A flexible connection made from a large inner tube permitted accurate weighings without disconnecting the blower.

a. Power requirements for blowing. The fan was driven by a 3 horsepower electric motor suspended in a frame, and equipped with a torque arm and spring balance, from which power calculations were made as discussed for the large bin.

The scales, bin, blower and motor were all assembled on a portable platform for ease in moving the equipment about.

Air velocities thru the bin were determined by means of a Pitot tube inserted in the connection between the blower and bin, and read with a manometer in inches of water. A vane type anemometer was used in the bin outlet and the calculations have been made from the anemometer readings.

b. Static pressure with varying velocities. Static pressure was read in inches of water, by means of a manometer inserted in the bin below the false floor and 90° from the blower inlet to avoid velocity influence.

Initial readings were made with the bin empty. The bin was then filled with ear corn in increments of one foot of depth, and readings made to determine power, static pressure and air velocity. Psychrometer readings were also made of the ingoing and outgoing air, but the amount of corn was too small to get significant readings.

c. Although weighings were made, and relative humidities and other related factors were recorded, insufficient data were secured in the work with the small bin to justify any conclusions concerning the rate of drying.

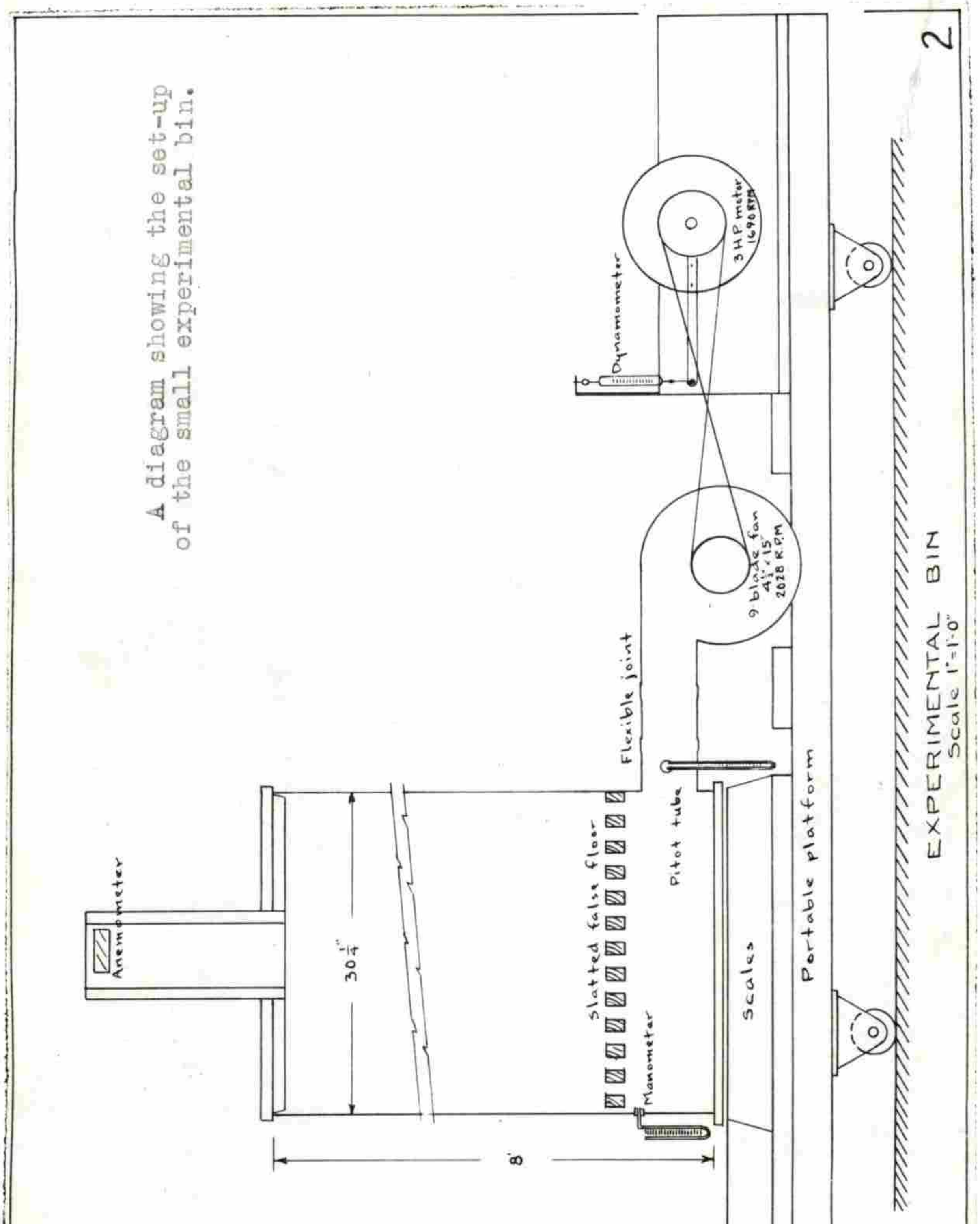

A diagram showing the set-up
of the small experimental bin.
2
Anemometer
30¼"
8'
Slatted false floor
Manometer
Pitot tube
Scales
Portable platform
Flexible joint
9 blade fan
4½" x 15"
2028 R.P.M
3 HP meter
1690 RPM
Dynamometer
EXPERIMENTAL BIN
Scale 1"=1'-0"

Chart No. 2

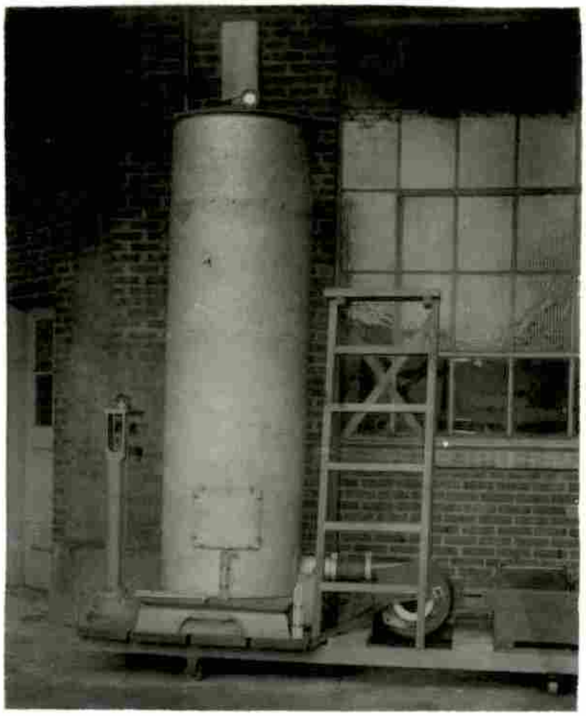


Figure No. 3
The small experimental bin used in this study.

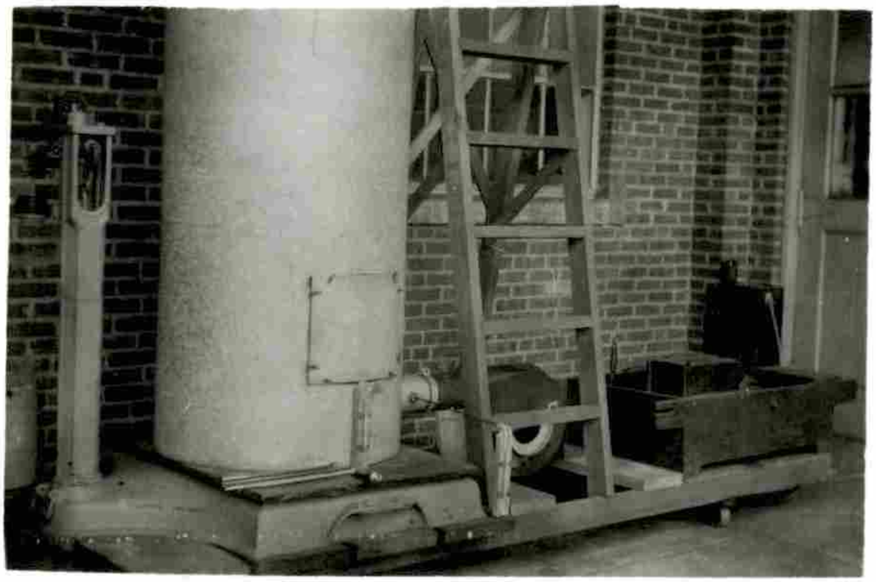


Figure No. 4
The equipment was assembled on a portable platform for convenience in using either indoors or outside. Any change in the moisture content of the corn could be determined immediately by the scales.

3. Botanical research. The need for a better understanding of the factors influencing the behavior of corn in storage prompted some investigational work in that field.

a. Determining the hygroscopic moisture of corn. To know what atmospheric conditions are necessary for conditioning corn with unheated air requires the determination of the hygroscopic moisture of corn in air of different relative humidities.

Two series of tests were conducted.

(1). Hygroscopic moisture of ear corn in air with 100% relative humidity. On January 18, 1930, eight glass desiccators were each loaded with 300 gram samples of ear corn from the large storage building. Each sample comprised a part of two different ears, and all were selected as typical of the average corn in the bin. The base of each desiccator was filled with water, to maintain the air at 100% relative humidity. The desiccator lids were sealed with vaseline. The corn was weighed daily for about two months, and after that at longer intervals, for a total period of about four months. The desiccators were kept in one of the botany research laboratories, which was maintained at about the usual room temperature. A thermograph was maintained on the shelf with the desiccators, and record kept of the temperature (and relative humidity) of the room. The temperature ranged from 60° to 82°F. with a mean of about 72°.

(2). Hygroscopic moisture of ear corn, shelled corn and cob in atmospheres of different relative humidities.

A second series of tests was begun on March 10, involving 48 samples. This group comprised sixteen 50-gram samples of ear corn, sixteen 10-gram samples of shelled corn and sixteen 10-gram samples of cob. One-half of each group had been thoroughly dried (before weighing) in an electric oven set to maintain a temperature of 95°C. The other half was direct from the storage bin. Small wire screen containers were made for the samples, four to each desiccator. The cob samples were laid over the shelled corn.

Samples in duplicate of each series were then placed in desiccators in which four different relative humidities were maintained by the use of sulfuric acid solutions of different concentrations. At the time of loading these samples, the relative humidities used were 100%, 90%, 75%, and 60%. The specific gravity of the solutions changed with the absorption and evaporation of water, so that at the conclusions of the tests, the specific gravity was determined, and the corresponding relative humidity used in the data presented.

(3). Table for relative humidities. The following table quoted from Dillman (5), and used by him, Coleman and Fellows (4), and others, was used in making up the solutions for the different relative humidities desired.

Table No. 1

Reference table for making humidity solutions of sulfuric acid and water.

Relative humidity Required %	Specific gravity Required
15	1.514
30	1.415
45	1.358
60	1.283
75	1.220
90	1.125

Table computed on H_2SO_4 of specific gravity 1.832. Temperature 25°C.

(4). Chart for relative humidities. For convenience in interpolating between values in the above table, the accompanying chart has been plotted. See Chart No. 3.

b. Determination of voids in ear corn. To secure a better understanding of the problem of moving air thru a bin filled with ear corn, a few tests were made to determine the per cent of voids in it.

A nominal 4-gallon stone jar was checked for volume, and after weighing was filled with ear corn. Due to the larger per cent of wall, as compared with a large bin, the amount of voids was excessive, and the weight of the corn less than the common allowance of 28 pounds per cubic foot (70 pounds ear corn per bushel). Shelled corn was therefore added until this density was obtained. The jar was then filled with alcohol, and quickly drained. Alcohol was used because of its slower absorption by the corn. The volume of the alcohol drained off divided by the total volume of the jar gave the per cent voids.

This method was repeated later, with water, except in filling the interstices to obtain the proper density, equal volumes of shelled corn and broken cobs were used.

4. Study of weather records. Daily weather records from the United States Weather Bureau at Des Moines were obtained for the period January 1917 to December 1930. According to Charles D. Reed, meteorologist at that station, the conditions reported in the noon readings are typical of at least four hours.

A study has therefore been made to determine the number of days which might reasonably be expected each month that would be suited for blowing unheated air thru corn to condition it. For lack of any standard for this purpose arbitrary limits have been used. As the drying effect of air at low temperatures or with high relative humidities is slight or may even add moisture, this study is based on days showing noon readings with a temperature of 40°F. or above, and a relative humidity of 80% or less.

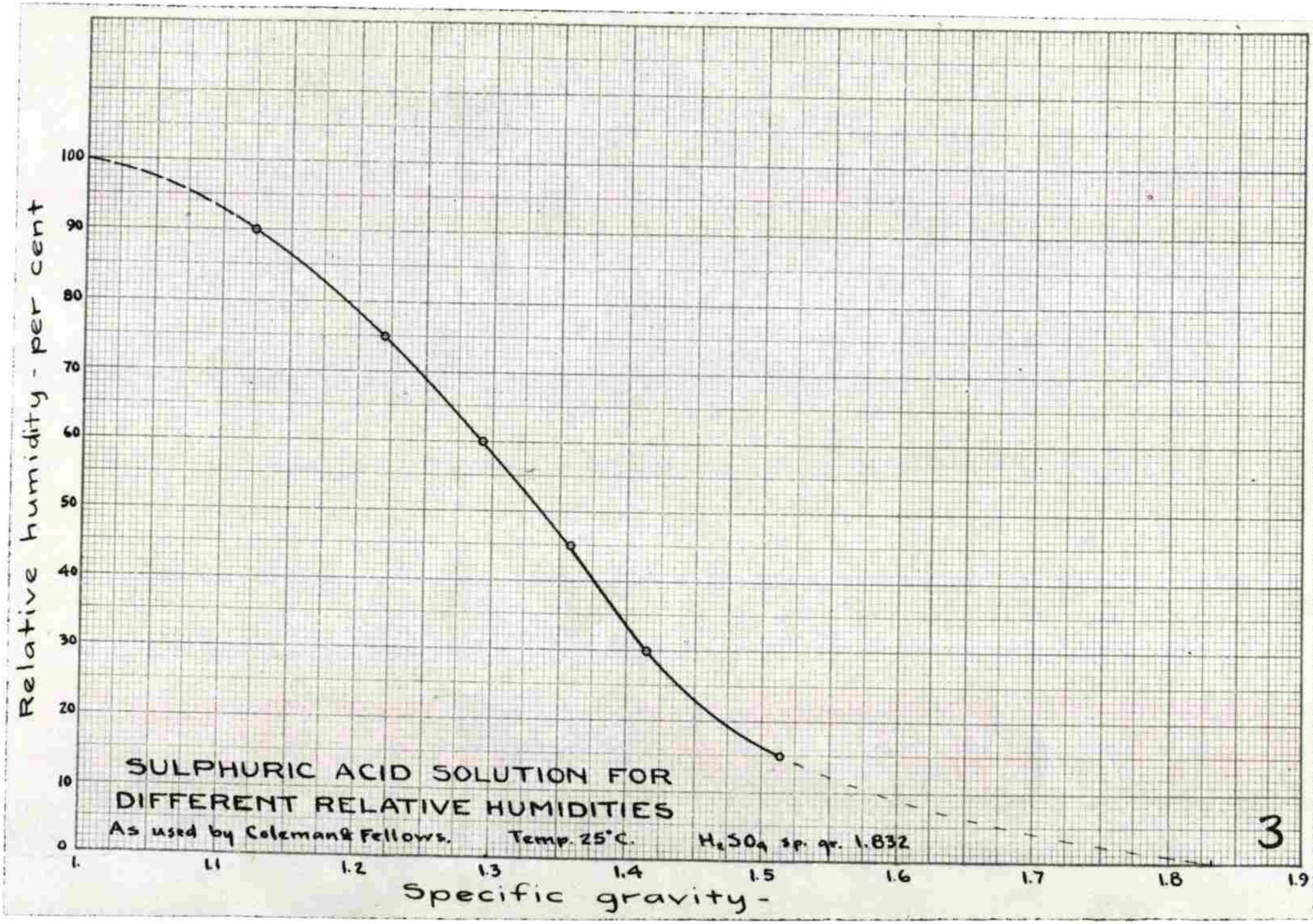


Chart No. 3. This curve is plotted from the values shown in Table No. 1.

Figure No. 5
Hygroscopic moisture determinations were made for different relative humidities in these desiccators.

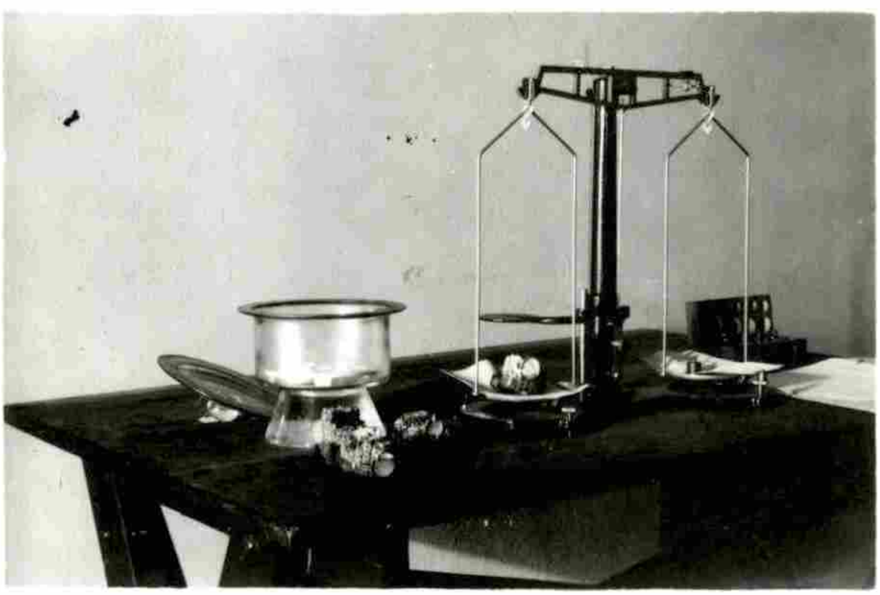


Figure No. 6
Frequent weighings were made to determine the rate of moisture absorption and evaporation.

C. Results

1. Observation of corn in large bin.

Table No. 2

Temperature readings, degrees Fahrenheit, at grain storage building. Ear corn in southeast bin.

	1929 Dec. 6	13	1930 Jan. 3	1930 Feb. 1	7	14	21	28	1930 March 7	14	15	17	19	21	24	28	1930 April 4	11	18	19
Mercury Thermometer	30	35	24	24	35	33	45	37	39	30	--	41	50	36	40	37	50	64	47	--
Air check Potentiometer	32	--	--	30	34	32	42	40	40	42	52	44	52	36	45	43	52	64	50	--
Thermocouple No. 1	--	--	- 40	23	31	36	39	44	52	47	43	46	49	44	50	53	45	54	68	69
2	35	41	38	28	26	30	30	30	36	38	36	40	43	42	46	48	47	56	80	86
3	29	40	33	22	23	35	36	42	38	43	40	44	48	45	45	49	43	54	62	61
4	28	36	32	22	21	26	27	28	31	35	38	36	39	35	40	44	42	45	52	52
5	Installed March 14									*138	112	*112	104	100	88	80	69	74	97	97
6	Installed March 15										48	55	50	50	51	48	48	62	70	64
7	Installed March 15										52	52	50	35	52	52	49	57	74	74
8	Installed March 15										52	46	44	50	46	50	48	52	74	76
9	Installed March 19												73	75	70	67	62	71	83	83

*Some of the corn at top near No. 5 moved.

Table No. 3.

Table showing moisture determination of corn, using Brown-Duvel Tester - Per cent moisture.

		1929 Nov. 22	1930 Jan. 10	17	18	31	Feb. 7	14	21	28	1930 Mar. 7	14	21	28	Apr. 4	11	18	25	May 2	9	16	23
Corn as cribbed	corn	20.*																				
	cob	25*																				
S.E. bin near top and outer wall	corn		18.3	16.7			19.4	19.5	20.5	20.2	20.1	21.1	19.9	19.4	20.6	17.8	20.2	18.6	18.2	19.5	18.3	18.2
	cob		17.2	19.			20.6	18.8	21.	21.6	22.7	23.8	20.8	21.4	21.	16.4	20.2	18.8	19.9	19.5		17.6
Corn from Bot. Lab.	corn		4.95	4.6																		
N.W. bin near top	corn				18.7	18.5																
	cob				20.4	18.9																
N.W. bin at bottom old corn	corn										15.9											
	cob																					
S.E. bin at top near chute	corn											22.6			18.2							
	cob											25.2										
S.W. bin as shelled	corn																	18.	18.9			
S.E. bin near couple 4	corn																				20.3	
																					22.	

*Determined by Dr. Bakke

The values shown in Table No. 3 represent the average of duplicate determinations.

Table No. 4

Table showing velocity
readings of natural ventilation.

Feet per minute thru bin.

	1930													
	Feb.					Mar.					Apr.			
Date	1	7	14	21	28	7	17	19	21	24	4	11	18	25
Up			.0835		0		.02	.125	.07	0	.0285		.095	.05
Down	.075	.0625		.094	0	.065				0		.1025		

Mean .0558

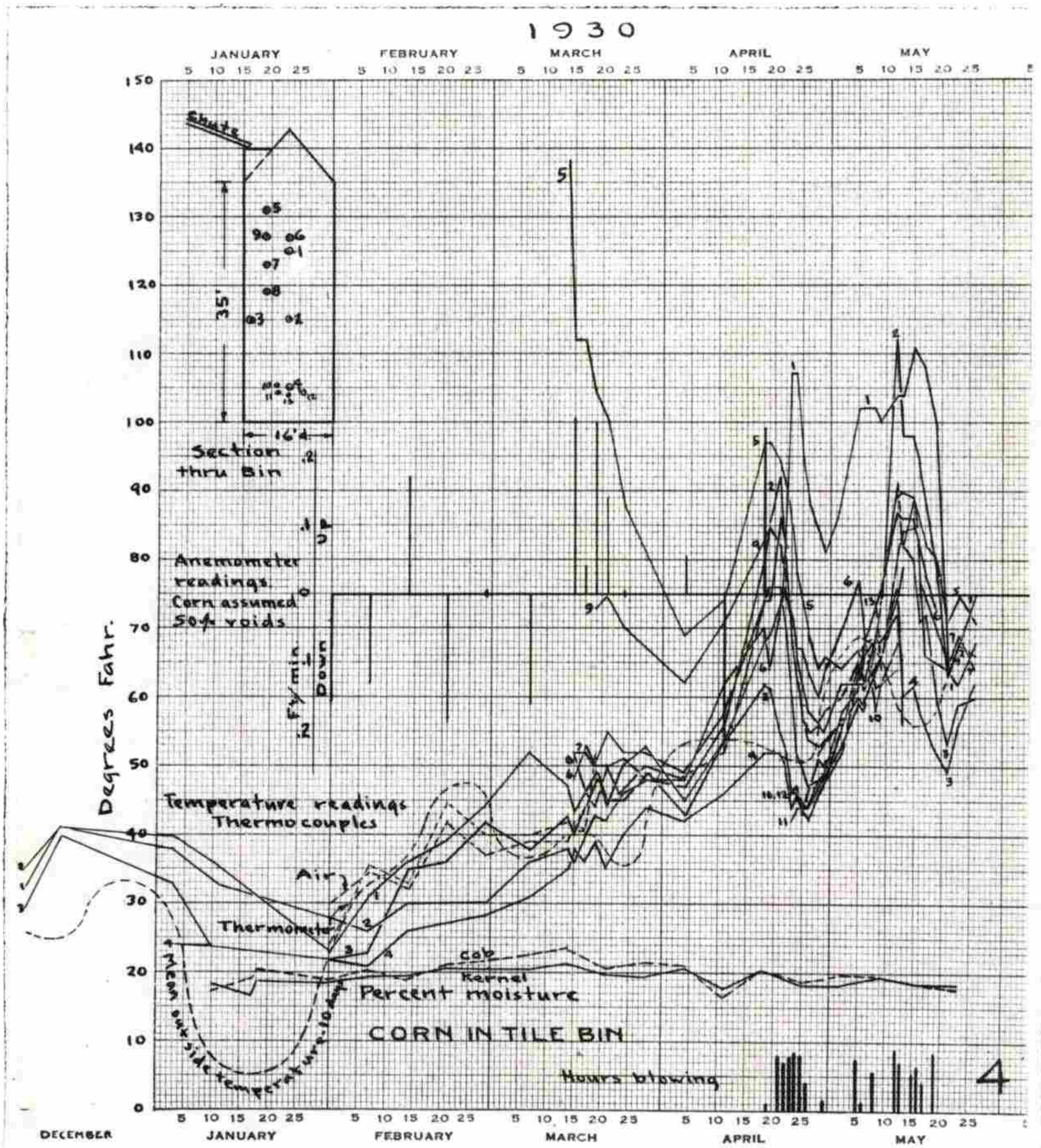


Chart No. 4
A graphic representation of results reported
in Tables Nos. 2, 3, and 4.

Table No. 5.

Table of temperatures in southeast bin after starting fan.

Degrees Fahrenheit

Date	April 19	20		21				22				23				24				25	
Hour	11:30	4	8	8	11:30	2	5	8	11:30	3:30	4:30	8:30	10:30	1:30	5	8	11:30	3	5	8	1:30	3:30
Air check: Thermo-couple	53	46	49	50	53	52	52	45	50	52	51	47	50	52		46	46	47	48	46	47	49
Mercury Ther-mometer	53	43	48	48	53	50	51	42	48	50	50	44	48	52		44	46	48	50	44	48	50
Couple No. 1	73	69	69	74	73	74	73	84	84	88	90	96	97	104	104	107	104	98	96	95	91	89
2	88	86	88	92	88	84	76	80	73	69	67	68	63	60	58	62	59	55	54	57	53	53
3	53	61	55	55	53	50	49	52	48	47	46	46	43	43	42	46	42	41	43	45	41	41
4	51	52	52	52	51	50	50	50	47	45	45	44	42	42	43	46	44	41	42	44	40	39
5	90	97	94	94	90	88	88	90	84	85	84	85	81	80	78	78	75	72	72	74	70	69
6	74	64	71	74	74	73	74	74	76	74	74	72	72	72	69	67	66	66	67	67	62	62
7	82	74	75	86	82	78	77	82	74	70	71	74	68	65	63	63	58	58	56	59	55	53
8	69	76	72	76	69	67	68	69	62	59	60	60	55	53	51	52	49	46	46	50	44	46
9	78	85	79	82	78	76	75	76	72	72	73	72	68	68	66	66	61	61	60	62	58	58
No. hours blowing	1		8					7				8				8.5				8		

Date	April 26		28	29		May 2	5			6		8		9		12			13		
Hour	8	12	8:30	2	4	7:30	8:15	2:45	4:30	10:30	11:45	9	2	5	7:30	8	1:30	5:30	10	1:30	5:00
Air check: Thermo-couple	48	53	52	68	66	64	69	75		69			64		64	61			56		
Mercury Ther-mometer	46		50	70	67	62	71	78		68					64	60			54		
Couple No. 1	88	84	84	80	81	86	98	102	102	98	102	102	99	94	100	104	100	98	104	102	103
2	55	50	56	55	54	62	62	62		62			69		73	110	104	98	98	93	89
3	44	40	48	49	48	58	61	61		66			68		68	72	65	59	60	58	58
4	44	41	47	48	47	55	55	63		68			69		67	76	64	59	60	58	57
5	69	66	64	64	66	64	66	67		62					66	70	69	74	75	78	82
6	64	60	60	61	64	70	77	73		68					76	87	86	86	86	84	84
7	54	51	53	52	54	57	59	60		59					66	83	89	89	90	86	84
8	47	45	48	48	48	53	56	59		58					74	91	89	82	82	74	72
9	58	56	56	58	58	60	62	65		61					66	75	80	82	84	84	83
No. hours blowing	3.5			1.5			7.5			1		5.5				9			7		

Date	May 15		16				17			19					21	23	26
Hour	8:00	1:30	8:30	9:30	12	3:30	8	9:45	11:30	8	9	11	11:30	4:30	8	8	8
Air check: Thermo-couple	57		56				48			51					67	59	65
Mercury Ther-mometer	57		57				46			53					69	58	65
Couple No. 1	111	107	109	106	104	103	108	102	101	99	98	88	70•	68	64	62	68
2	98	91	94	91	87	79	88	78	73	78	72	66	64	62	63	68	75
3	62	59	58	55	54	54	56		50	50	46	44	46	53	49	56	62
4	62	•58	54	52	54	54	56		48	49	48						
5	89		85			81	82		78	80			72	75	72	75	71
6	86		82			75	78		73	73•							
7	89		78			69	65		66	65			61	61	59	64	64
8	80		72			65	74		79	60			48	54	53	59	60
9	85		78			73	74		69	71			62	65	64	68	66
No. hours blowing	5.5		6.5				4			8.5							Total 100 hours

•Thermo-couple uncovered.

Thermo-couple No. 1 which was located in a dense pocket of shelled corn did not respond to the blowing as did the remainder of the readings.

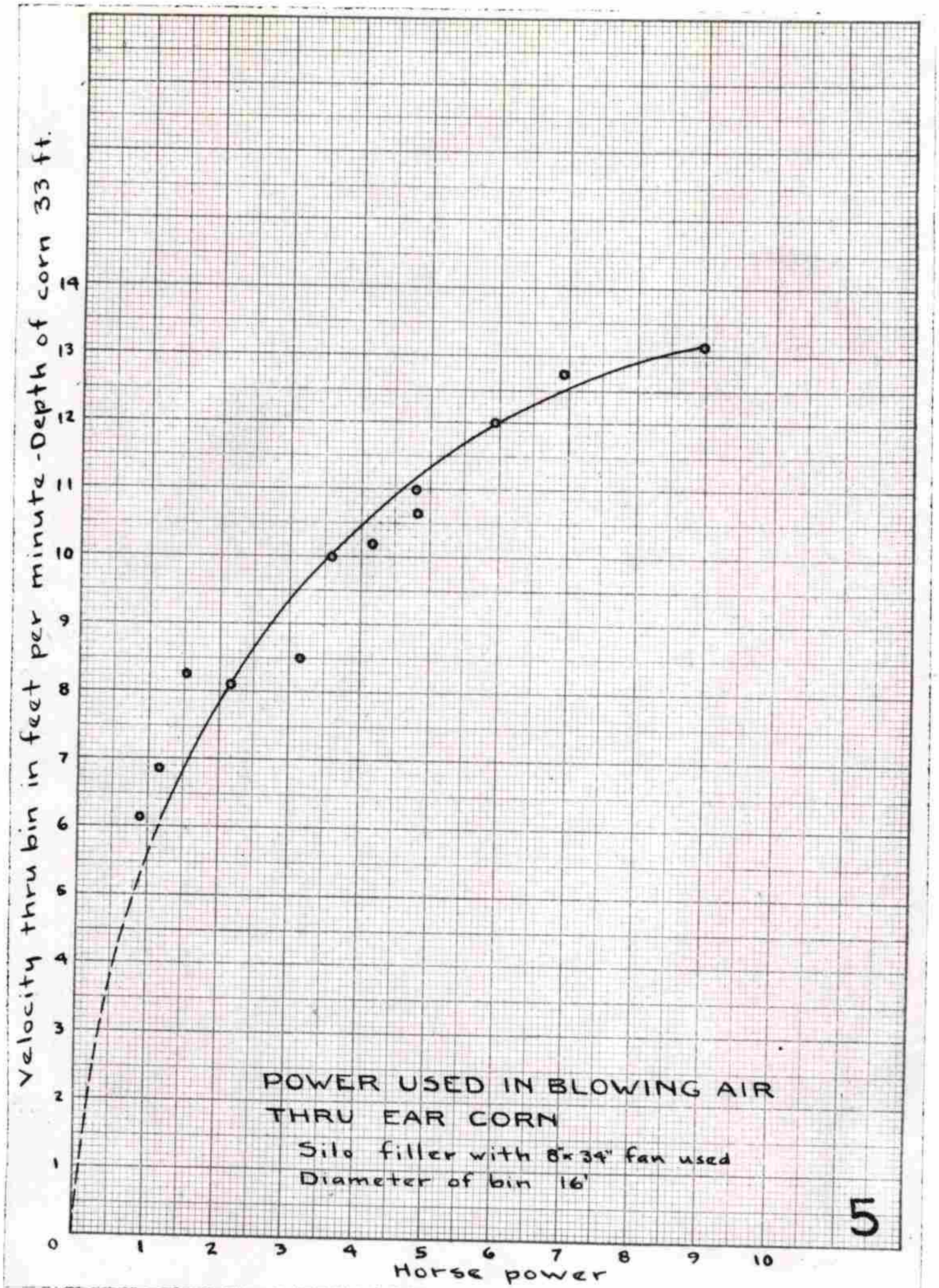


Chart No. 5
The economy in power in using low air velocities
in blowing is evident from this curve.

Table No. 6.

Table showing amount
of moisture removed from corn in south-
east bin by blowing

Date	April 19	21	22	23	24	25	26	29	May 5	6	8	12	13	15	16	17	19	Totals
Average dry bulb temp. ingoing air		48.4	50.8	54.2	50.8	54.3	54.3	72.5	77.3	69.0	66.0	62.5	53.6	55.8	54.0	45.0	53.3	
Average wet bulb temp. ingoing air		41.8	41.3	43.0	40.0	41.5	44.4	62.5	67.8	61.0	58.3	53.2	46.6	48.8	47.5	37.8	49.0	
Average relative humidity, ingoing air %		57.0	43.0	48.0	48.0	28.0	43.0	57.0	61.0	64.0	64.0	54.0	58.0	61.0	62.0	51.0	73.0	
Average dry bulb temp. outgoing air		57.3	54.5	53.5	53.9	54.0	50.3	67.5	70.8	70.0		71.2	64.5	59.5	60.5	56.8	55.0	
Average wet bulb temp. outgoing air		55.3	51.7	49.7	49.6	49.9	47.7	57.5	65.8	65.5		68.0	61.5	58.0	57.8	54.5	52.5	
Average relative humidity, outgoing air %		88.0	82.0	76.0	74.0	76.0	84.0	74.0	77.0	79.0		86.0	85.0*	92.0	86.0	85.0	85.0	
Average moisture in outgoing air grains per cu.ft.		4.6	3.7	3.5	3.3	3.6	3.5	4.7	6.3	6.2		7.0	5.5	5.1	5.0	4.4	4.1	
Average moisture in ingoing air grains per cu.ft.		2.1	1.7	2.2	2.0	1.3	2.0	4.7	5.9	4.9		3.2	2.7	3.0	2.8	1.7	3.3	
Average moisture (M) grains absorbed per cu.ft.	** 1.8	2.5	2.0	1.3	1.3	2.3	1.5	0.0	.4	1.3	** 1.8	3.8	2.8	2.1	2.2	2.7	.8	
Hours blowing 2000 cu. ft. per minute	1.0	8.0	7.0	8.0	8.5	8.0	3.5	1.5	7.5	1.0	5.5	9.0	7.0	5.5	6.5	4.0	8.5	100
Lbs. water evaporated - $\frac{\text{Hrs. x 60 x 2000}}{7000}$ x M	31	343	240	178	190	316	90	0	51	22	169	587	336	283	244	185	116	3381

*Condensation appeared on bin wall above corn.
**Average of values on other dates.

The advantage of selecting days with low relative humidities for blowing with unheated air is apparent in the above table.

2. Work with small experimental bin.

Table No. 7

Table showing horsepower,
static pressure and velocity readings,
with small experimental bin 30 1/4" diameter.
3 H.P. electric motor 1690 R.P.M., Fan 2028 R.P.M.

Depth of ear corn in feet	0	1		2	3	4	5		6	7
Horsepower	.94	.93	.93	.96	.91	.86	.86	.815	.815	.815
Static pressure in inches of water	.2	.4	.3	.565	.6	.775	.85	.9	1.	1.1
Velocity thru bin in feet per minute	88.7	93.1	92.	93.2	90.5	93.5	90.6	86.3	87.1	87.8

The data in Table No. 7 is presented graphically in Chart No. 6.

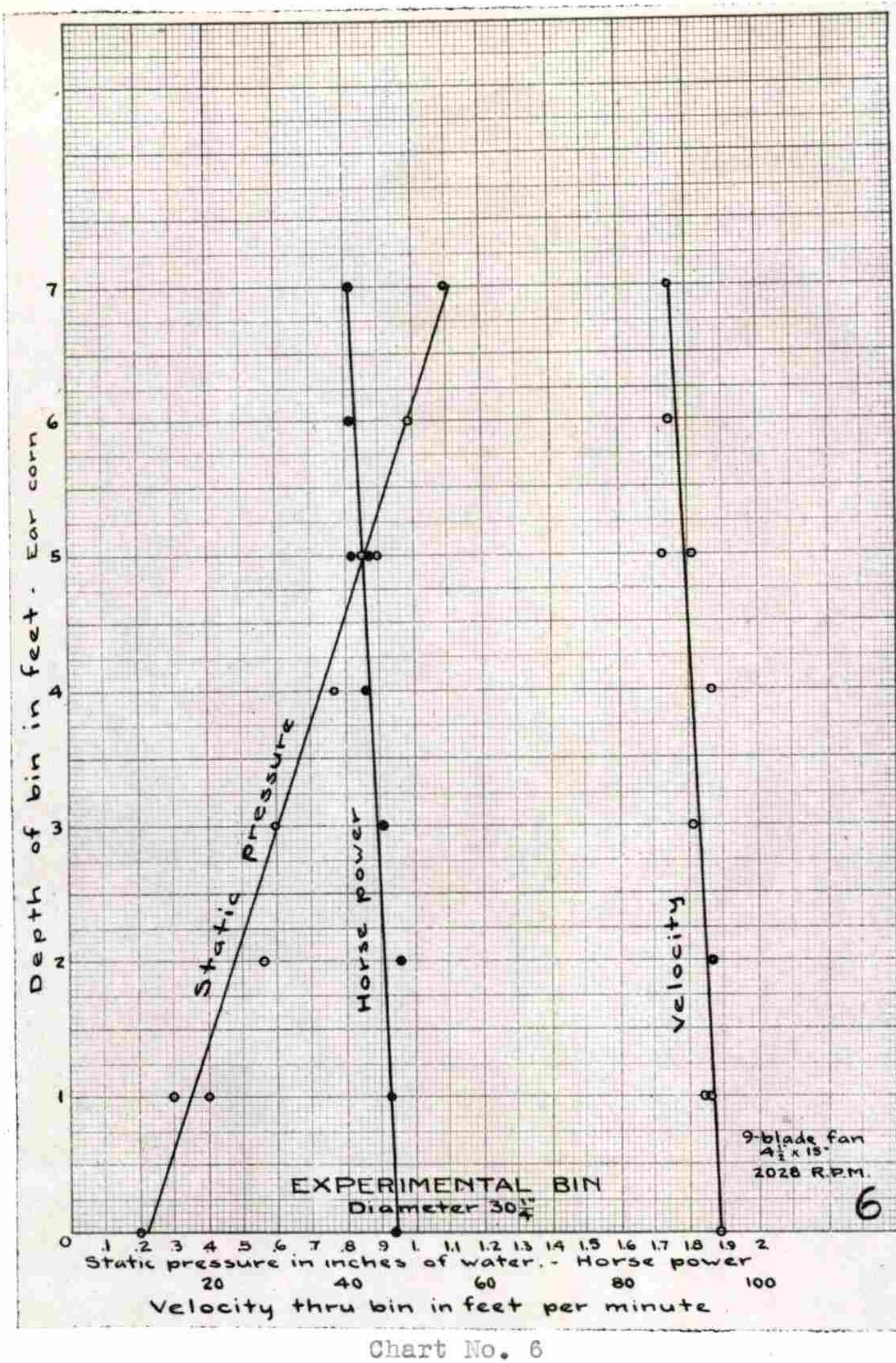


Chart No. 6
Curves showing power used, static pressure and velocity of air thru corn in small experimental bin. From data in Table No. 7.

3. Botanical Research.

a. Determining hygroscopic moisture.

Table No. 8 is based on the test described on page 22.

Table No. 8.

Table showing moisture absorption of ear corn in atmosphere with 100% relative humidity.

300 gram samples, moisture analysis corn 18.7%, cob 20.4%. Readings show weight in grams.

	January 1930											February					
Date:	18	20	21	22	23	24	25	27	28	29	30	31	1	3	4	5	6	7
No. 1	300	304.5	305.0	305.0	305.5	306.2	306.9	308.2*	308.3	309.2	309.8	310.2	310.6	311.6	312.0	312.4	312.2	312.7
2	300	303.0	303.5	303.5	304.3	304.7	305.2	306.2*	306.4	306.7	307.0	307.3	307.8	308.7	309.1	309.5	309.7	309.8
3	300	304.0	304.5	304.9	305.3	305.9	306.7	307.8	308.0	308.3	308.5	308.8	309.3	310.0	310.6	310.6	310.4	310.6
4	300	303.5	304.2	304.3	305.2	305.8	306.6	307.8*	308.0	308.7	309.0	309.4	310.1	311.2	311.6	311.8	311.8	311.8
5	300	303.0	303.5	304.3	304.7	305.6	306.7	307.5*	307.7	308.3	308.7	309.0	309.3	310.6	311.3	312.0	312.3	312.6
6	300	303.5	304.0	305.0	305.8	307.0	308.0	309.7*	310.3	311.0	311.3	312.5	313.3	315.2	316.3	316.8	317.2	317.7
7	300	303.5	304.0	304.2	305.4	306.1	307.0	308.2	308.8	309.5	310.0	310.7	311.2	313.2	314.5	315.2	315.6	316.4
8	300	302.5	303.0	303.0	303.5	304.5	305.6	307.0	307.8	308.0	308.7	309.2	309.8	311.0	311.7	312.0	312.2	312.6

	February																March
Date:	8	10	11	12	13	14	15	17	18	19	20	21	24	25	26	27	28	1
No. 1	312.9	313.8	313.8	314.2	314.1	314.3	314.6	315.0	315.2	315.4	315.6	315.7	316.5	317.1	316.6	316.4	316.3	316.0
2	310.2	310.9	311.0	311.2	311.5	311.7	312.2	312.5	312.5	312.7	312.8	312.8	313.7	314.0	313.9	313.7	313.9	313.7
3	310.6**	310.1***	309.3	309.0	308.8	308.6	308.4****	308.3	308.3	308.4	308.4	308.6	309.2	309.6	309.5	309.3	309.9	309.2
4	312.3	312.8	313.0	313.2	313.3	313.5	313.7	314.0	313.9	313.9	314.0	314.0	314.4	314.8	314.7	314.5	314.9	314.5
5	312.8	313.4	313.7	314.0	314.2	314.4	314.9	315.0	315.3	315.5	315.6	315.7	316.5	316.8	316.7	316.5	316.7	316.7
6	318.3	319.5	320.0	320.5	321.4	321.5	322.1	322.7	323.1	323.1	323.6	323.7	324.9	325.5	325.4	325.3	325.7	325.5
7	317.0	317.4	317.9	318.1	318.7	318.9	319.4	319.9	320.1	320.4	320.5	320.8	321.9	322.3	322.2	322.2	322.3	322.2
8	313.0	313.9	313.9	314.2	314.3	314.5	314.7	315.0	315.2	315.4	315.6	315.7	316.4	316.8	316.8	316.7	317.2	316.9

	March															April	
Date:	3	4	5	6	7	8	10	11	13	15	17	19	21	24	27	31	3	7
No. 1	315.7***	315.6	315.2	314.8	314.9	314.6	314.0	314.0	313.4	313.1	312.3	311.5	310.9	310.0	310.0	310.3	310.5	310.5
2	313.8	313.5	313.5	313.3	313.3	313.0	313.1	313.4	313.5	313.6	313.5	313.2	313.1	312.7	312.7	312.9	313.0	312.9
3	309.1	309.0	309.0	308.9	308.6	308.2	308.1	308.1	307.9	307.8	307.6	307.1	306.8	306.3	306.4	306.7	306.8	306.8
4	314.6****	314.2	314.0	313.8	313.9	313.5	313.3	313.4	313.2	313.4	313.1	312.6	312.1	311.9	311.7	311.8	312.0	312.1
5	316.8	316.7	316.6	316.5	317.0	316.3	316.6	316.8	316.9	317.2	317.1	316.9	316.8	316.6	316.7	316.7	316.8	316.6
6	326.0	325.8	325.7	325.6	325.9	325.8	326.4	326.7	327.0	327.5	327.8	327.8	328.0	325.3**	326.2#	326.8	327.1	327.3
7	322.5	322.4	322.1	322.2	322.8	322.3	322.4	322.9	323.2	323.7	324.0	324.1	324.2	324.5	325.0	325.8	326.2	326.5*
8	317.0	316.9	316.9	316.6	316.6	316.4	316.7****	316.9	317.1	317.4	317.4	317.2	317.2	317.1	317.2	318.0	318.2	318.4

	April				May			
Date:	10	14	17	24	1	8	15	22
No. 1		312.1		315.7				
2		313.8		315.2				
3		308.2		310.0				
4		313.5		317.2				
5		317.1		318.0				
6	327.7	328.2	328.3	329.5	330.5	331.1	331.4	332.2
7	326.9	327.3	327.7	328.5	328.2	328.8	329.6	330.5
8		319.2		320.4				

*Mold appearing on broken end of cob.

**Mold appearing on kernels.

***Badly molded condition.

****Corn in bad condition--kernels soft.

#Lid found loose on desiccator.

The above data are shown graphically in Chart No. 7.

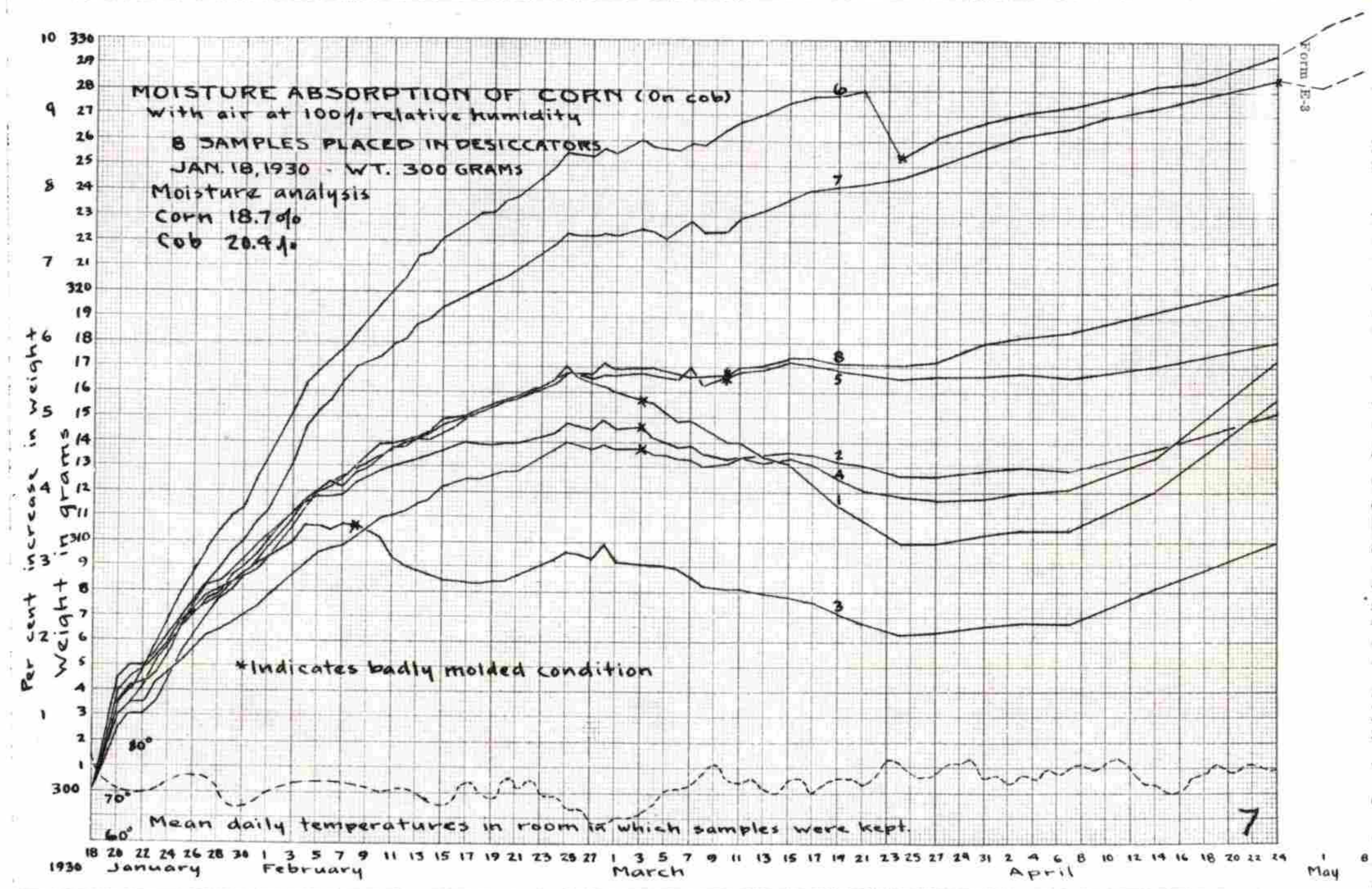


Chart No. 7
Moisture absorption of ear corn, from data in table No. 8.

Eight desiccators, containing forty-eight corn samples, were used to secure the data in table No. 9

Table No. 9.

Table showing moisture absorption of shelled corn, cob, and ear corn in atmospheres of different relative humidities. Moisture analysis, corn 20.1%, cob 22.7%. Readings show weight in grams.

Desiccator No.	Relative humidities Mar.	Relative humidities May	Material	No.	March 10	11	13	15	17	19	21	24	27	31	April 3	7	10	14	17	24	May 1	8	15	22
9	100	100	Oven dried	21	10	10.7	11.4	11.9	12.25	12.5	12.65	12.85	12.95	13.0	12.95	12.95	12.9	12.95	12.95	13.15	13.45	13.6		
			corn	22	10	10.9	11.65	12.1	12.45	12.8	12.75	12.9**	12.95	13.05	13.05	13.0	12.9	12.9	12.95	13.25	13.5	13.85		
			Corn from	45	10	9.7	9.95	10.1	10.3	10.3	10.4	10.5	10.6	10.65	10.65	10.65	10.5	10.4	10.4	10.5	10.7	10.2		
			bin	46	10	9.7	9.95	10.1	10.3	10.3	10.4	10.5	10.6	10.65	10.65	10.7	10.55	10.55	10.6	10.7	10.9	10.25		
			Oven dried	21c	10	11.0	11.5	11.7	12.05	12.15	12.3	12.5	12.6	*12.7	12.8	12.85	12.9	13.05	13.1	13.1	13.15	13.25	13.3	13.35
			cob	22c	10	10.9	11.45	11.65	12.0	12.05	12.15	12.3	12.5	*12.6	12.7	12.7	12.75	12.8	12.85	12.9	12.85	13.0	13.1	13.25
			Cob from	45c	10	10.2	10.45	10.55	10.6	10.85*	10.9	11.0	11.15	11.25	11.35	11.3	11.3	11.4	11.45	11.4	11.6	11.65	11.7	11.85
			bin	46c	10	10.2	10.45	10.6	10.85	11.0	*11.05	11.15	11.25	11.35	11.45	11.45	11.45	11.6	11.65	11.55	11.8	11.85	11.95	11.95
10	90	85	Oven dried	23	10	10.8	11.25	11.5	11.65	11.7	11.7	11.75	11.75	11.8	11.8	11.8	11.8	11.8	11.8	11.85**	11.8	11.8		
			corn	24	10	10.8	11.25	11.5	11.65	11.7	11.75	11.8	11.85	11.85	11.85	11.85	11.85	11.85	11.85	11.9	11.9	11.9		
			Corn from	47	10	9.6	9.6	9.6	9.6	9.65	9.65	9.7	9.8	9.8	9.8	9.75	9.75	9.75**	9.75	9.8	9.75	9.75		
			bin	48	10	9.6	9.65	9.65	9.65	9.7	9.7	9.75	9.75	9.75	9.75	9.75	9.75	9.75	9.75	9.75	9.85	9.9		
			Oven dried	23c	10	10.9	11.15	11.2	11.3	11.3	11.35	11.4	11.4	11.4	11.45	11.4	11.45	11.45*	11.45*	11.45	11.45	11.5		
			cob	24c	10	10.85	11.15	11.2	11.3	11.35	11.4	11.4	11.45	11.45	11.45	11.45	11.5	11.5	11.5	11.5	11.5	11.5		
			Cob from	47c	10	10.05	10.05	10.05	10.1	10.1	10.1	10.1	10.15	10.15	10.2	10.1	10.15	10.15*	10.15*	10.15	10.15	10.15		
			bin	48c	10	10.15	10.15	10.15	10.2	10.2	10.2	10.2	10.25	10.25	10.25	10.2	10.25	10.25	10.25	10.25	10.35	10.35		
11	75	68	Oven dried	25	10	10.7	10.95	11.05	11.2	11.25	11.25	11.3	11.35	11.35	11.35	11.35	11.35	11.3	11.35	11.4	11.35	11.4		
			corn	26	10	10.8	11.0	11.1	11.2	11.2	11.2	11.25	11.3	11.3	11.3	11.3	11.25	11.25	11.3	11.35	11.3	11.3		
			Corn from	49	10	9.5	9.4	9.35	9.35	9.35	9.35	9.4	9.4	9.4	9.4	9.35	9.35	9.35	9.35	9.4	9.35	9.35		
			bin	50	10	9.5	9.35	9.35	9.3	9.3	9.3	9.35	9.35	9.35	9.35	9.35	9.3	9.3	9.35	9.35	9.3	9.3		
			Oven dried	25c	10	10.8	10.9	10.9	10.9	10.9	10.95	10.95	11.0	11.0	11.0	10.95	10.95	11.0	11.0	11.0	11.0	11.0		
			cob	26c	10	10.95	10.95	10.95	10.95	10.95	10.95	11.0	11.0	11.0	11.0	10.95	10.95	11.0	11.0	11.0	11.0	11.0		
			Cob from	49c	10	10.0	9.9	9.85	9.9	9.85	9.85	9.85	9.85	9.8	9.85	9.8	9.8	9.8	9.85	9.85	9.85	9.9		
			bin	50c	10	10.05	9.95	9.9	9.9	9.9	9.9	9.9	9.9	9.85	9.9	9.85	9.9	9.9	9.9	9.9	9.9	9.9		
12	60	55	Oven dried	27	10	10.6	10.7	10.8	10.85	10.9	10.95	11.0	11.0	11.05	11.05	11.0	11.0	11.0	11.0	11.1	11.05	11.05		
			corn	28	10	10.55	10.6	10.75	10.8	10.85	10.9	10.95	10.95	11.0	11.0	11.0	10.95	10.95	11.0	11.05	11.1	11.1		
			Corn from	51	10	9.3	9.2	9.2	9.15	9.15	9.15	9.15	9.15	9.15	9.15	9.1	9.1	9.1	9.15	9.2	9.2	9.3		
			bin	52	10	9.1	8.95	8.95	8.95	8.9	8.9	8.9	8.9	8.9	8.9	8.9	8.9	8.9	8.9	8.9	9.0	9.05		
			Oven dried	27c	10	10.6	10.65	10.7	10.7	10.65	10.7	10.7	10.7	10.7	10.7	10.7	10.7	10.7	10.7	10.7	10.7	10.75		
			cob	28c	10	10.6	10.7	10.7	10.7	10.7	10.75	10.75	10.75	10.75	10.75	10.75	10.75	10.75	10.75	10.75	10.75	10.75		
			Cob from	51c	10	9.8	9.65	9.6	9.6	9.6	9.55	9.55	9.55	9.55	9.55	9.55	9.55	9.55	9.55	9.55	9.55	9.55		
			bin	52c	10	9.5	9.3	9.25	9 .25	9.25	9.2	9.25	9.25	9.2	9.2	9.2	9.2	9.2	9.2	9.2	9.2	9.2		
13	100	100	Oven dried	37	50	53.65	55.25	56.8	58.1	58.85	59.7	60.65	61.4	62.0	62.25	62.65	62.9	63.25	63.45*	64.15	65.2	65.95	66.25	66.1
			ear corn	38	50	53.9	55.55	56.6	58.1	59.05	59.7	60.5	61.2	61.9	62.15*	62.5	62.8	63.1	63.35	63.9	65.1	65.7	66.05	66.0
			Ear corn	29	50	47.6	48.0	48.0	48.4	48.55	48.85*	49.15	49.5**	49.85	50.2	50.5	50.75	51.05	51.25	51.65	52.35	52.65	52.7	52.7
			from bin	30	50	48.4	48.7	49.2	49.1	49.45	49.65*	49.9	50.25	50.75	51.1	51.3	51.6	51.9	52.1	52.55	53.5	53.8	53.8	53.8
14	90	87	Oven dried	39	50	53.95	55.1	56.0	56.95	57.3	57.65	58.1	58.4	58.7	58.9	58.95	59.0	59.1	59.2	59.2	59.5	59.55		
			ear corn	40	50	53.45	54.95	55.9	56.7	57.25	57.25	58.0	58.4	58.6	58.7	58.8	58.9	59.0	59.1	59.2	59.45	59.45		
			Ear corn	31	50	47.3	47.5	47.4	47.35	47.4	47.5	47.6	47.7	47.9	47.85	47.85	47.9	47.95	48.0	48.0	48.0	48.1		
			from bin	32	50	47.9	47.85	47.8	47.85	47.7	47.85	48.0	48.1	48.1	48.2	48.2	48.3	48.35***	48.4	48.35	48.5	48.5		
15	75	68	Oven dried	41	50	52.9	53.7	54.3	54.9	55.2	55.45	55.75	55.9	55.95	56.05	56.05	56.05	56.1	56.1	56.1	56.15	56.2		
			ear corn	42	50	54.2	55.1	55.7	56.05	56.25	56.4	56.55	56.65	56.65	56.75	56.75	56.8	56.8	56.75	56.75	56.9	57.0		9
			Ear corn	33	50	47.95	47.25	46.75	46.45	46.4	46.3	46.2	46.2	46.1	46.15	46.1	46.1	46.1	46.15	46.1	46.05	46.1		
			from bin	34	50	47.75	47.05	46.6	46.35	46.25	46.2	46.15	46.15	46.1	46.15	46.1	46.1	46.1	46.15	46.05	46.1	46.15		
16	60	55	Oven dried	43	50	52.75	53.3	53.8	54.2	54.45	54.6	54.85	54.95	55.0	55.05	55.05	55.05	55.1	55.1	55.1	55.1	55.2		
			ear corn	44	50	52.45	53.35	53.85	53.95	54.1	54.3	54.45	54.6	54.65	54.7	54.7	54.7	54.7	54.8	54.75	54.8	54.8		
			Ear corn	35	50	47.25	46.5	46.0	45.85	45.5	45.35	45.2	45.2	45.15	45.15	45.1	45.1	45.1	45.15	45.05	45.15	45.1		
			from bin	36	50	47.3	46.6	46.15	45.85	45.85	45.55	45.4	45.4	45.35	45.35	45.3	45.3	45.3	45.3	45.25	45.3	45.3		

*Mold on cob.
**Mold on kernel.
***Bad condition.

For a graphic presentation of the above data see Chart No. 8.

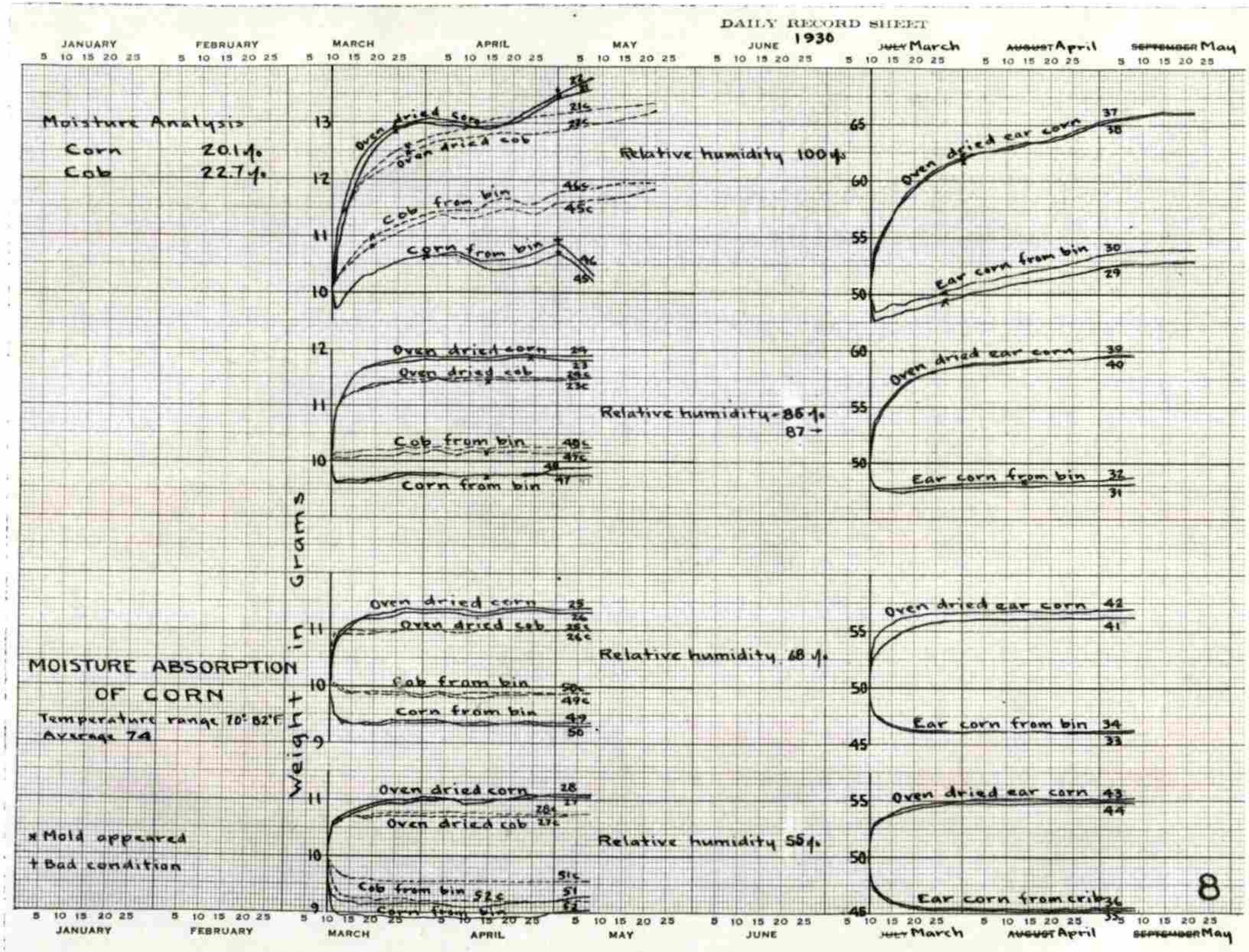


Chart No. 8
Curves showing the moisture absorption of corn. From data in table No. 9.

Temperature and varietal differences in corn influence the hygroscopic moisture content.

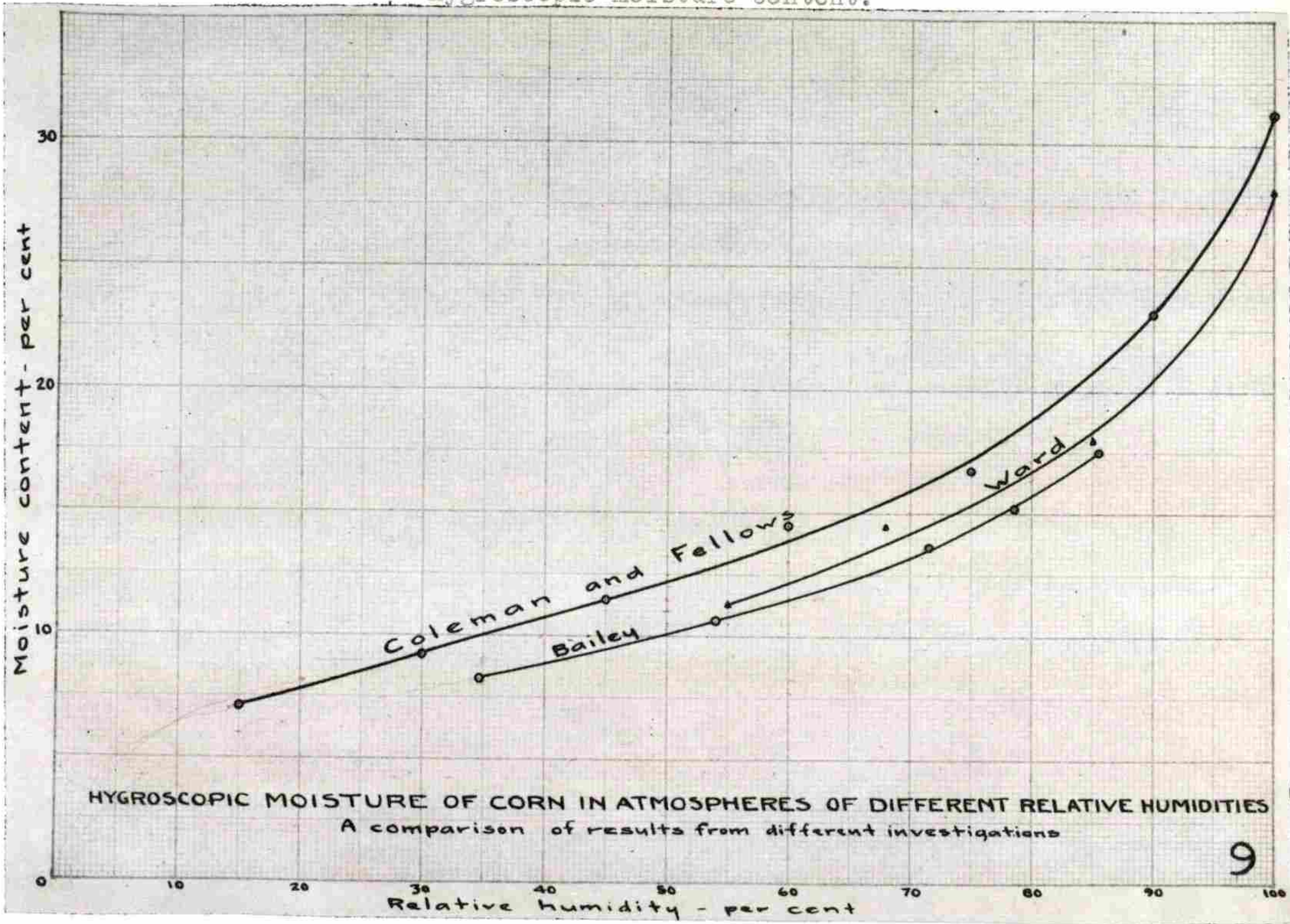


Chart No. 9
A comparison of results from different investigations, shows reasonably close agreement.

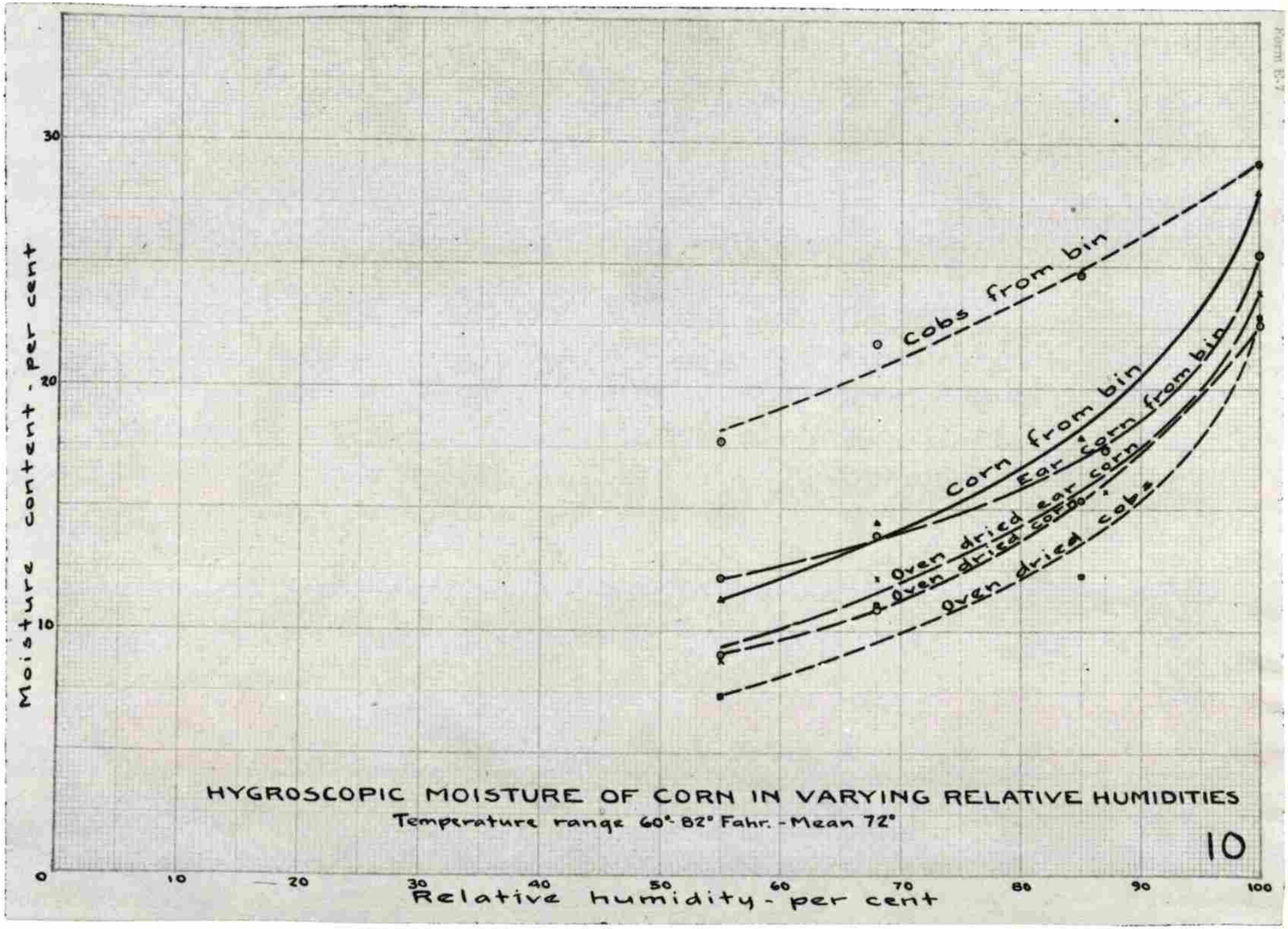


Chart No. 10.
Showing a mean of the values from table No. 9.

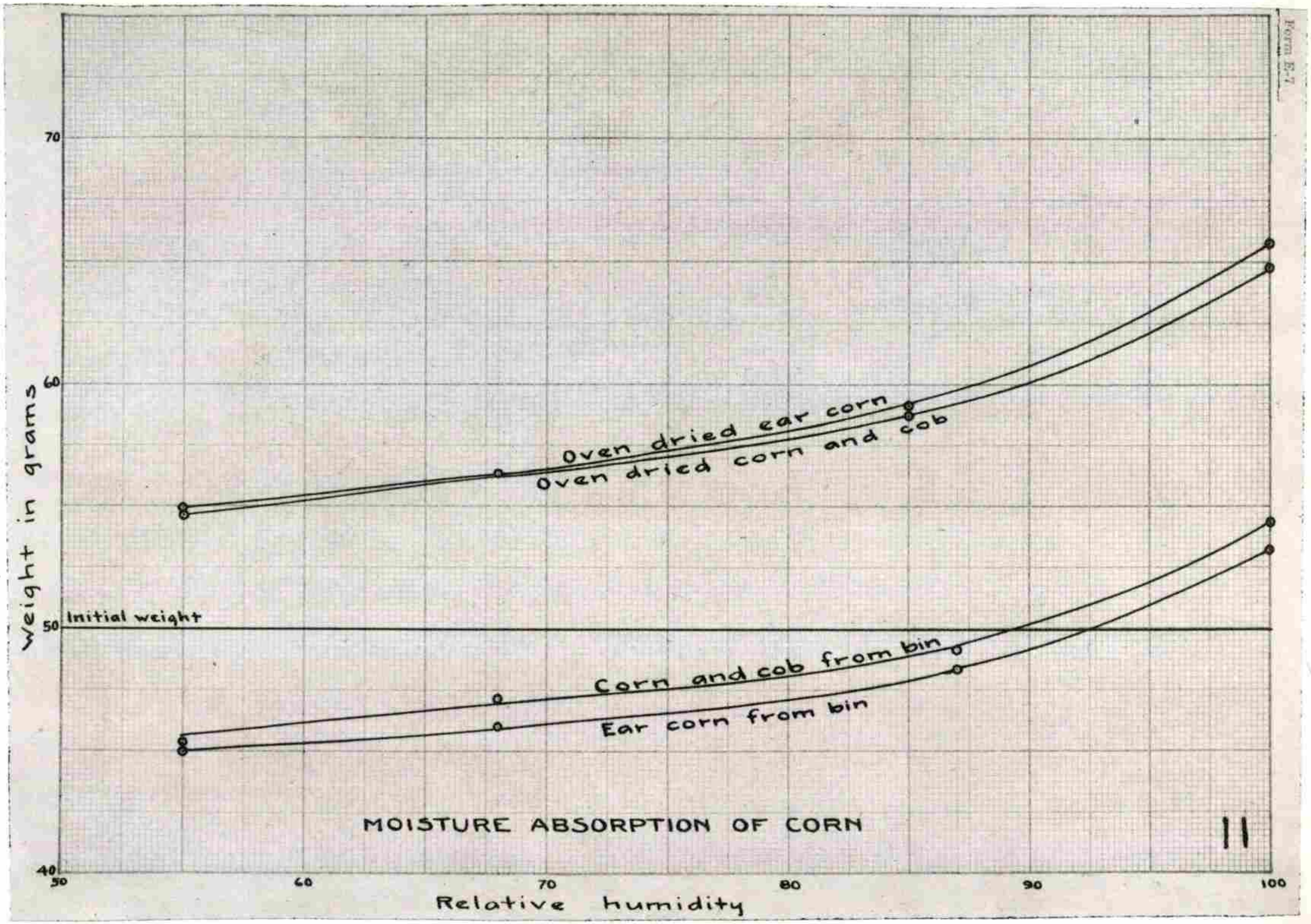


Chart No. 11
Moisture absorption of corn, as recorded in table No. 9.

b. Determination of voids in ear corn.

Table No. 10

Table showing determinations of voids in ear corn

	% voids
Density of 28 lbs. per cubic foot obtained by adding shelled corn.	48.
Density of 28 lbs. per cubic foot obtained by adding shelled corn and broken cob.	41.
Density of 28 lbs. per cubic foot obtained by adding shelled corn and broken cob.	40.5

The relatively high percentage of voids in ear corn explains the low pressures found in blowing with fairly high velocities.

D. Study of weather records

Table No. 11
Table showing number of days suitable
for blowing corn with unheated air.

Days - Temperature 40° or above with relative humidity 80% or less Des Moines Noon readings 1917-1930.

	J.	F.	M.	A.	M.	J.	J.	A.	S.	O.	N.	D.	Yearly total	Monthly average
1917	5	4	17	26	30	27	31	31	26	25	18	3	243	20.25
1918	0	9	23	28	29	28	30	30	29	26	13	13	258	21.5
1919	14	4	20	18	30	27	31	27	25	23	14	2	235	19.58
1920	0	0	16	20	29	29	30	28	27	29	11	4	223	18.58
1921	6	7	16	24	29	29	29	28	28	31	13	8	248	20.66
1922	3	6	18	23	28	30	28	28	28	29	18	9	248	20.66
1923	2	4	11	24	28	29	31	20	21	26	18	14	228	19.0
1924	1	6	8	27	29	20	28	27	28	29	19	3	225	18.75
1925	2	20	21	30	30	27	31	26	27	21	17	7	259	21.58
1926	5	10	9	25	29	28	26	30	19	26	5	4	216	18.0
1927	8	9	20	18	25	27	31	30	27	28	10	3	236	19.66
1928	8	8	16	19	30	29	29	28	28	27	14	6	242	20.16
1929	0	1	19	25	31	28	28	30	28	23	16	7	236	19.66
1930	3	12	18	25	28	27	30	28	29	22	22	4	248	20.66
Average	4.1	7.2	16.5	25.5	29.0	27.4	29.5	27.9	26.2	26.1	14.8	6.2	239	19.9

A graphic presentation of these data is shown in Chart No. 12.

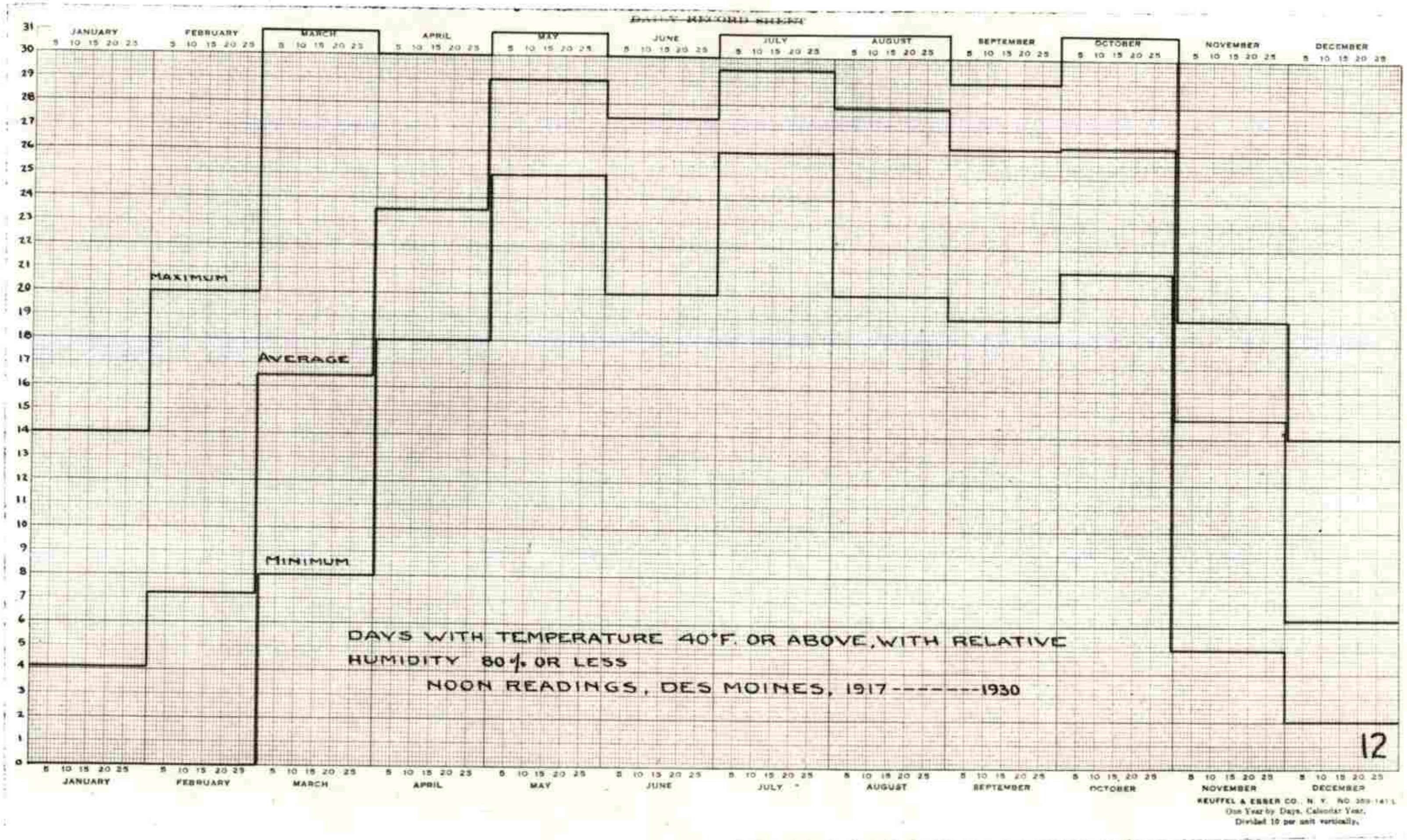


Chart No. 12
From the Des Moines weather records, as indicated in table No. 11

To be in condition for safe summer storage, corn should meet, as nearly as possible, the requirements for No. 1 grade as indicated in Table No. 12.

Table No. 12.

Table showing U. S. standard corn grades

No.	Min. test wt.	Moisture %	Maximum foreign material and cracked corn %	Damaged total %	Kernels heat damaged		
1	55	14.0	2	2	0.0	cool	sweet
2	53	15.5	3	4	0.1	"	"
3	51	17.5	4	6	0.3	"	"
4	49	19.5	5	8	0.5	"	"
5	47	21.5	6	10	1.0	"	"
6	44	23.0	7	15	3.0	"	may be sour
Sample							

Moisture content is the principal index as to the keeping quality of corn.

IV. DISCUSSION

A. Observation of Corn in Large Bin

1. As might reasonably be expected the temperatures in the large bin continued favorable until the outside temperature increased appreciably.

2. The data secured indicate it is unsafe to rely on tight bins of this size for keeping corn thru hot weather, without blowing either heated or unheated air thru to condition it. The reduction in moisture content from the time of filling in November and December until blowing was started in April was too slight to make any marked improvement in the grade of the corn.

3. The number of velocity readings obtained was too small to justify an accurate figure on the natural air movement thru the corn. They do, however, give an indication of the slow rate of natural drying to be expected in this type of storage. The average drying effect of each cubic foot of air blown thru the bin was calculated to be 1.972 grains. Assuming an equal value for air moving thru the corn naturally, and that a minimum of four pounds of water must be removed from each bushel for safe summer storage, it would require 6 years, 9 months to condition the corn.

4. Forced ventilation appears to be a requirement with this type and size of storage unit. Whether this should be

with heated or unheated air depends on the conditions involved. If seed corn is to be handled, the rate of drying with unheated air is too slow to assure its safety from decrease in viability due to freezing. If the corn is only for market purposes, a longer period is available for its conditioning, which may be accomplished with unheated air.

a. Power requirements for blowing air thru ear corn are not excessive. But little significance should be given the actual power consumed in this test. The blower and its connections were perhaps as inefficient as they could well be. The blower designed for blowing ensilage is not likely to be efficient in blowing air only, against a static head. The plan and construction of the building made necessary the use of four 90° elbows between the fan and the space beneath the floor. There is little doubt that an efficiently designed installation would show a much lower power consumption. The important factor to be found in the power chart is the rapid increase in power with increase in velocity of the air. With other conditions constant, therefore, the blowing of corn can be done most economically by moving the air at low velocities and pressure. When blowing this bin at the rate of 2,000 cubic feet per minute, a manomometer showed a static pressure of only .5 inch of water. Thus, the power and pressure requirements are easily met.

To take advantage of this principle, it would be essential to install blowing equipment that would operate with a minimum of attention. An installation requiring the full time of an operator would make the cost needlessly high per bushel of grain conditioned.

b. The data concerning the removal of moisture while blowing unheated air show the necessity of selecting favorable weather conditions for that purpose. During the 100 hours actual blowing approximately 3381 lbs. of water were evaporated from the corn. The gasoline engine was used 35 hours, and during that time consumed 24 gal. gasoline and 6 qts. lubricating oil. Calculating these at .195 and .80, respectively, per gallon the cost for these two items was $5.88 or .168 per hour. On this basis the cost per pound of water evaporated was .005¢, or to remove 4 pounds per bushel .02¢. With the most favorable condition during the test more than 60 pounds of water were evaporated per hour while the least favorable calculation shows 6.8 per hour, with an average of 33.8.

On May 15 sufficient corn was removed from the bottom of the bin to form a tunnel in to couple No. 4, and observe the condition of the corn in that part of the bin. The corn appeared to be in good condition though still showing about the same moisture content as when cribbed. Considerable shelled corn was found in removing this corn, as the path of the tunnel lay directly under and in front of the filling chute.

Couple No. 1, located 25 feet above the floor, did not respond as readily to blowing as did the other readings, so on

May 19 an excavation was made from the top, extending down to this couple. In removing the corn for this purpose a narrow oblong core was found which was perceptibly warm, and included an abnormal amount of shelled corn. The width of this core corresponds closely with that of the chute, in front of which it is located. When the thermo-couple was reached, it was found to be located in this dense core which resisted the circulation of air. A few inches either side of the dense core, the corn was cool, and the air from the blower which was in operation, was easily felt. Though somewhat warm, most of the corn in the core was in fair condition. A few ears were found in bad condition, and on some, mold was present. The concentration of the shelled corn in a bin of this kind, is perhaps the most difficult problem to meet, so far as conditioning the corn is concerned. The air moving thru the bin naturally travels where the resistance is least and thus, leaves the denser portions with little ventilation. Any method of filling which would reduce the amount of shelled corn, or insure its uniform distribution would be favorable to this type of storage. For this particular building, it is recommended that slatted chutes should be used between the elevator head and the bins, the shelled corn thus screened out being allowed to discharge into one of the small overhead bins for early use.

If the tight bins are to continue in use for the storage of ear corn, it is recommended that a fan should be installed in the basement, complete with motor ready for use at any time. The fan selected should have a capacity of at least 5,000 cubic feet per minute when running at normal speed. It should be installed with permanent ducts to the two south bins, and so arranged as to blow thru either or both as desired.

To facilitate further investigational work the motor should be variable speed, or the motor and fan should be equipped with cone pulleys which would permit quick changes of speed.

The most likely location for such a blower would seem to be near the pneumatic hoist, probably about where the air pump is now located. By excavating this space to the level of the basement floor it should be feasible to make permanent ducts to each bin without blocking the present passage way.

B. Work With Small Experimental Bin

The velocities of the air blown thru the small experimental bin were approximately eight times that blown thru the large bin. This accounts for the proportionately greater power consumption in blowing thru a bin with only 1/40 the cross-sectional area, and about 1/5 the depth of corn when filled. A significant factor to be observed on chart 5 is the decrease in power consumed as the bin was filled. It will be noted, of course, the velocity of the air decreased slightly also thus reducing the total volume of air delivered by the fan. With this, naturally, there was an increase in static pressure.

An interesting comparison may be made in the amount of air delivered and power required with the same static pressure in the large and small bins. The only static pressure accurately determined for the large bin was .5" with a velocity of 10 feet per minute thru about 33 feet of corn. This required approximately 3.5 horsepower to furnish the 2,000 cubic feet of air (cross-sectional area 200 square feet). (See chart 6.) Approximately the same pressure was required in the small bin, when blowing thru only two feet of corn with a velocity of 93 feet per minute. Thus, 465 cubic feet of air (cross-sectional area of bin 5 square feet) required .9 horsepower, which is slightly more in proportion to the volume of air delivered, and was blowing thru only 2 feet of corn in contrast with 33 feet in the large bin.

C. Botanical Research

1. Perhaps one of the most important fundamental facts pertaining to grain conditioning, coming from this study, is that concerning the hygroscopic moisture capacity. It is probable that engineers generally have overlooked this factor in conducting experiments in the conditioning and storage of corn and other grain. The close agreement of the determinations made with those of previous investigators would seem to warrant the use of the values found, at the temperature range of the investigations. Additional determinations are needed, for

other temperatures, to make the use of these data entirely dependable at all practical storage conditions.

In addition to hygroscopic moisture determinations, the curves on charts 7 and 8 afford some information on the rate at which corn takes up and gives up hygroscopic moisture. In general, the process is a relatively slow one, which would seem to offer an additional reason for favoring low velocity blowing.

Another very significant observation made incidental to the original purpose of the tests concerns the presence of molds on the corn. The curves are marked to indicate the first appearance of mold. It may be noted, the samples in the two lower relative humidity series showed no mold. Some of the samples maintained in 85 and 87% relative humidities showed a little mold growth. Several appeared entirely free of mold at the conclusion of the test which lasted 73 days. In no case did either cob or kernel show sufficient mold development with these relative humidities to make any appreciable change in the quality. The samples maintained in 100% relative humidities were all in bad condition at the conclusion of the tests.

Chart 8 shows other interesting results. Attention is called to the character of the curves for corn and ear corn from the bin where placed in 100% relative humidities in the same desiccators with oven dried corn. It is clearly evident the oven dried corn absorbed the atmospheric moisture more rapidly than it was evaporated from the free surface of the water, so that the atmosphere for a time was much less humid than the nominal value. A comparison with the curves on chart 7 where no oven dried corn was used, confirms the interpretation. The presence of the oven dry material is, perhaps, largely responsible for the increase in specific gravity of the sulfuric acid solutions.

Another significant factor is also to be found in a study of chart 8. The left-hand series of curves records the behavior of the kernel and cob separately, while the right-hand series shows the results from ear corn under identical conditions. The comparison is most striking in the materials from the bin, giving up moisture in the two lower series. Shelled corn samples 49 and 50 practically reached equilibrium in 3 days, while the ear corn samples 33 and 34 required about 10 days. A similar statement would hold for shelled corn samples 51 and 52 and ear corn samples 35 and 36.

The changes in weight of the oven dried shelled corn were consistently more rapid than for the ear corn. This confirms the statement reported by the Illinois Experiment Station that shelled corn dries more quickly than ear corn. This suggests the need for a thorough test of conditioning and storing shelled corn, instead of on the cob. If such is found practical, the storage buildings for corn could be reduced one-half in size, and the saving thus effected should be more than needed for the installation of suitable conditioning equipment.

The cooperative project started in 1930 between Iowa State

College and the Collins Farm Company, Charles City, Iowa should furnish valuable data on the storing of shelled corn in tight-walled bins. The first year's corn was abnormally dry at the time of harvesting with a corn combine, so the results thus far should not be regarded as typical of what might be expected.

2. The rather large per cent of voids found in ear corn seems favorable for artificial drying. The avoidance of concentration of shelled corn in the bin is the most serious problem involved.

D. Weather Records

While the study of weather records from Des Moines is not directly applicable to all of the corn producing areas, a corn production map shows it is not far from the center of the corn belt. Perhaps, half of this area has climatic conditions equally, if not more favorable, while the other half may be less favorably situated for conditioning corn with unheated air. One season's results would not justify definite conclusions, but the indications seem to be that Iowa has sufficient favorable days for blowing corn with unheated air to condition it for safe summer storage. This may require operating the blower as soon as picking commences on all days that are favorable. For conditioning seed corn in tight bins, unheated air would ordinarily be too slow to be dependable.

V. CONCLUSIONS

1. Natural ventilation is inadequate for storing corn in large tight bins. The rate of natural air movement thru the corn indicates a period of years would be required to condition a crop of corn for safe summer storage.

2. Seed corn to be stored in large tight bins should be conditioned with heated air. The rate of drying with unheated air is too slow to insure against damage by freezing.

3. Market corn may be conditioned with unheated air by selecting favorable weather for blowing. To do this economically, the drying equipment should be selected to operate with little cost for labor. Care should be used in filling tight bins to secure uniform density.

4. Power requirements for blowing are not excessive. Low air velocities are most efficient from the standpoint of power consumed.

VI. SUMMARY

1. Moisture removal is the important problem in conditioning corn and other grain.

2. Hygroscopic moisture varies with the relative humidity of the atmosphere.

3. Large tight bins are not to be relied on without artificial conditioning.

4. Seed corn stored in large tight bins should be conditioned with heated air.

5. Market corn may be conditioned with unheated air if favorable days are used for blowing.

6. Care must be used in filling large bins to avoid concentration of shelled corn.

7. Power requirements for blowing corn are reasonable. The greatest efficiency is obtained with low velocities. Good results were secured moving the air at the rate of ten feet per minute thru the bin.

8. Shelled corn dries more quickly than ear corn.

9. Mold develops on corn only with high relative humidities, perhaps above 85%.

10. Ear corn in a bin has in excess of 40% voids.

11. Iowa has sufficient favorable weather to condition market corn with unheated air.

12. Tight-walled storage buildings for ear corn should be equipped with blower, and shelled corn should be screened out when filling.

VII. ACKNOWLEDGMENTS

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